DEVELOPMENT OF A THEORETICAL FORMULA FOR CALCULATING AIR FLOW THROUGH WOVEN MATERIALS UNDER CERTAIN RESTRICTED CONDITIONS

BY

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FORMULA FOR CALCULATING AIR FLOW
THROUGH WOVEN MATERIALS UNDER
CERTAIN RESTRICTED CONDITIONS

A thesis presented to the Faculty of the Lowell
Textile Institute as a partial requirement for the
degree of Master of Science in Textile Engineering

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PURPOSE

The purpose of this thesis was to develop an accurate method of predicting air flow through woven fabrics of various materials and having varied constructions. The thesis is made up of two phases. Phase I deals with verification of basic theory as applied to wire mesh. Phase II covers the same verification as applied to fabrics in general.

THEORY

The standard pressure drop across a fabric used to measure air flow is 0.5 inches of water. Calculating the velocity of such a drop gives the following:

$$V = 2\ gh$$

$$V = (2)\frac{(32.2\text{ ft.})}{\text{sec.}}\quad \frac{.5\text{ in.}}{12\text{ in.}}\ \text{ft.}$$

$$V = 1.64\text{ ft./sec.} = 1.1\text{ mi./hr.}$$

With such a low velocity, the flow of air through the fabric is a viscous or streamline flow with no turbulence. Furthermore, the quantity of air getting through is determined by the smallest area of each interstice.

Assume a theoretical plane through the fabric which would pass through the smallest cross-sectional area of each hole or interstice. If it were possible, accurately, to calculate the area of interstices in this plane, the result would be effective air space, or that air space through which the air is passing to get from one side of the fabric to the other. Assuming solid ends and picks, the air can get through the fabric only by passing through these interstices. An accurate method is presented herein to measure the % air space through this theoretical plane, and a correlation of this % air space and air flow at the very low 0.5 inch drop across the fabric is also presented to support the above theory.

PHASE I

Material

The first phase of testing was done on twelve wire meshes having the specifications given in the table below:

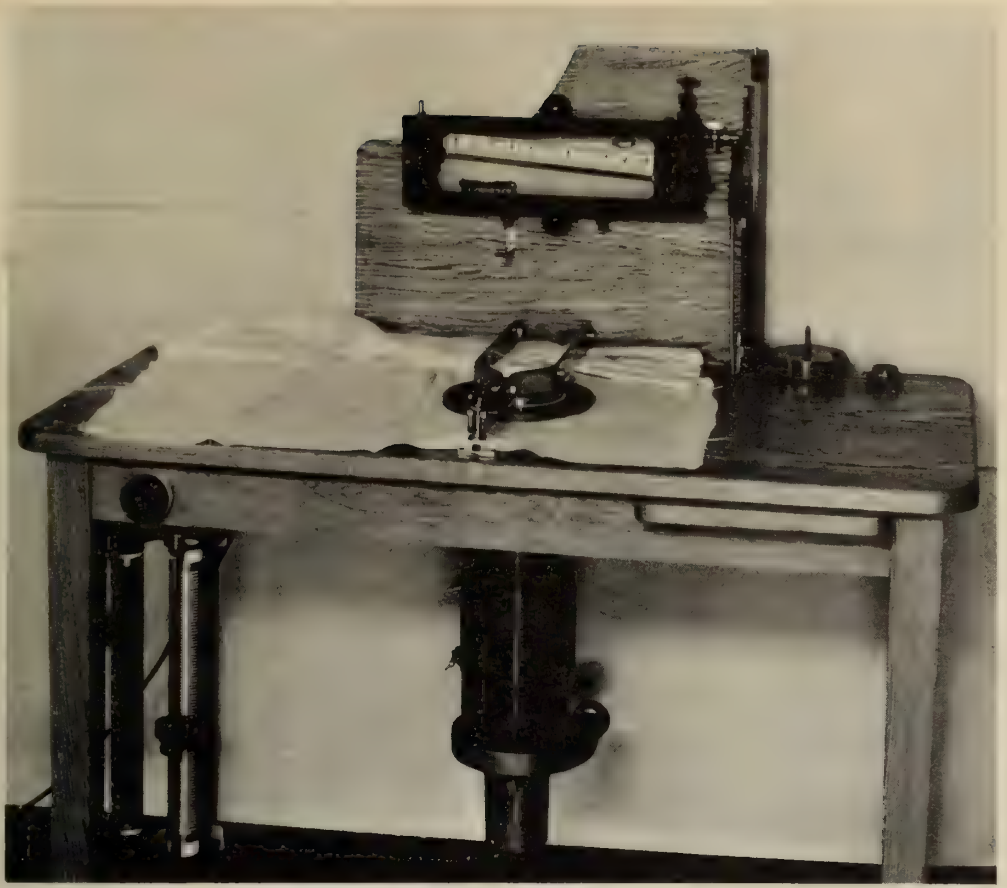
	Material	Diameter of Wire (in.)	Ends/Inch	Picks/Inch
1	Brass	.0260	8	8
2	Steel	.0205	10	10
3	Steel	.0200	14	14
4	Steel	.0095	30	30
5	Steel	.0197	18	18
6	Brass	.0100	40	33
7	Steel	.0154	24	24
8	Brass	.0070	60	50
9	Brass	.0035	120	101
10	Brass	.0050	90	76
11	Steel	.0087	50	50
12	Steel	.0100	45	42

APPARATUS

The apparatus which was used in Phase I of this thesis is described in Research Paper No. 261 of the Bureau of Standards entitled, "A Portable Instrument for Measuring Air Permeability of Fabrics" by H. F. Schiefer. (See P. 10 for illustration.)

The fabric to be tested is mounted under slight tension between the fabric orifice rings (diameter of opening 2.75 inches, area of opening 5.94 square inches). The outer ring weighing three pounds is placed over the fabric, acting as a slight pretensioning device. The fabric is then held in place by means of the clamp. Air is drawn through the fabric and through the calibrated air orifice by means of the suction fan. The speed of the suction fan motor which draws air through the fabric and the two chambers is controlled by two rheostats; a high resistance one for rapid changes in speed, and a low resistance one for fine changes or adjustments. The manometers are filled with a special oil, and calibrated with this oil to read in terms of inches of water pressure. The pressure drop across the fabric, measured by the inclined manometer which has a slope of 1 to 10, is brought to 0.5 inch of water by adjusting the speed of the suction fan. The pressure drop across the air orifice is then

noted on the vertical manometer. The volume of air passing is calculated from this value and the calibration data of the orifice. The air permeability of the fabric is expressed in cubic feet of air per minute per square foot of fabric at a pressure drop of 0.5 inch of water across the fabric.



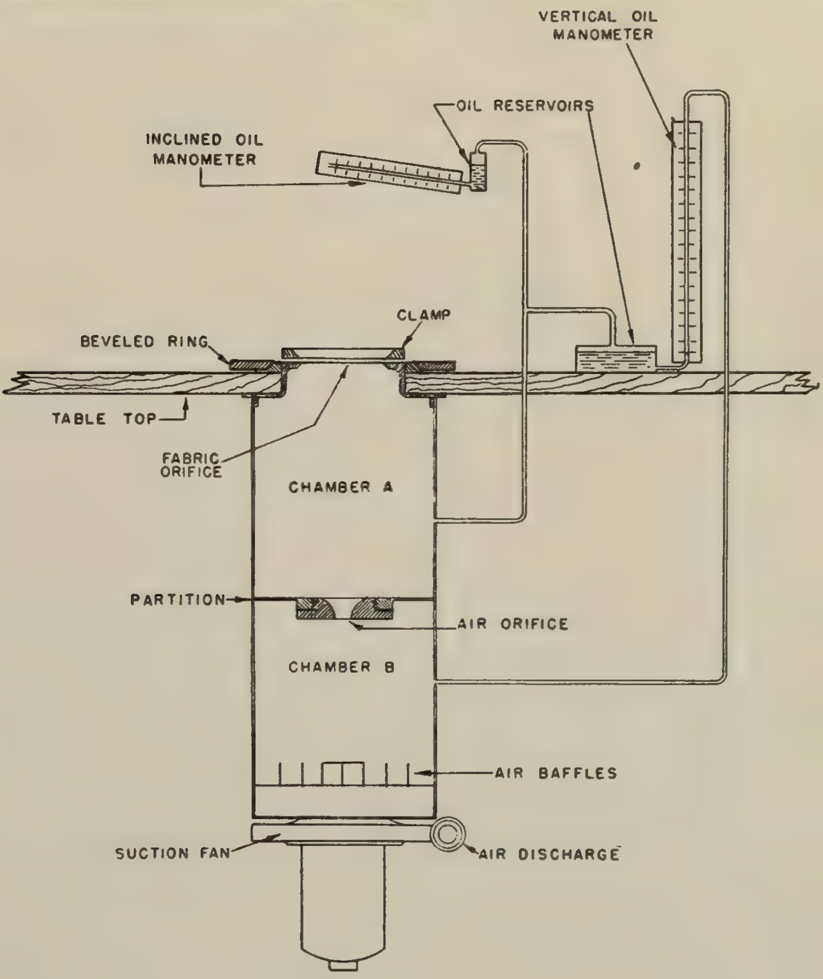


Fig. III.13. National Bureau of Standards Air Permeability Machine. Above: Machine as Made by Sherman W. Frazier. Opposite: Schematic Diagram of the Machine.

Courtesy Sherman W. Frazier

PROCEDURE

The apparatus was set up as shown in the schematic diagram on Page 10. A special sponge rubber ring of 2 inch thickness was placed under the beveled ring and the clamp was then lowered into place, the object of the sponge rubber being to insure that no air was being drawn from around the edges of the mesh. It was imperative that this air tight arrangement be made so that measurement of air flow represented only that air coming through the fabric orifice itself.

A further variation of the basic machine set-up was necessary to obtain the desired 0.5 inch drop across the mesh. The original fabric orifice had an area of opening of 5.94 square inches, this area being too great to effect the desired pressure drop. To get the desired drop, special round paper orifices ranging from 0.5 square inches to 3 square inches (in increments of 0.25 square inches) were cut from heavily waxed paper and clamped over the mesh being tested.

Five air flow readings for each paper orifice on each mesh were taken. Average values were then calculated for each orifice on each of the twelve meshes. These data are recorded on Pages 14 through 19, summarized on Page 20, and shown in graphical form on Pages 25 through 36. The calibrated air orifices used were those of 6.05, 8.15, and 11.00 mm. diameter

and a constant 0.3 inch drop was maintained across the mesh.

Calculations were then made to determine the per cent air space for each mesh based on the area of the interstices. Also, a correlation between per cent air space and air flow was made to form a basis for further investigation of actual fabrics of similar construction to that of the wire mesh.

Plots on Pages 25 through 36 were made as follows: average air flow for each mesh was the ordinate, while the abscissa was paper orifice area. Least squares equations were calculated as shown on Page 22 and the straight line plots were thus derived for each of the twelve wire meshes. The plot on Page 37 was made by merely transferring each of the twelve least squares lines to one common graph, each of the twelve lines being labeled to show a specific wire mesh. To arrive at the plot on Page 38, the air flow values for each of the twelve meshes were picked off of the plot on Page 37 for the 3 in^2 paper orifice, and these values were plotted against the per cent air space value corresponding to each of the twelve meshes. This gave twelve points from which to calculate a least squares line for the 3 in^2 paper orifice. Similar procedure was used to plot the 2 in^2 orifice line and the 1 in^2 orifice line.

The average equation was calculated from the data of the plot on Page 38. The 3 in^2 line and the 2 in^2 line

were reduced to a common base, the base selected being 1 in^2. Page 39 shows the calculation from which the average equation was derived. Plot on Page 40 was then made of per cent air space vs. air flow.

DATA

8 X 8 .0260" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices .50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	162	231	283	345	418	464	537	612	673	720	720
2	163	233	285	345	419	464	538	612	672	720	720
3	162	233	287	344	417	462	539	613	673	720	720
4	166	234	287	343	417	467	538	610	671	720	720
5	165	230	285	347	417	465	540	612	673	720	720
Total	818	1161	1427	1724	2088	2322	2693	3059	3362	-	-
Mean	164	232	285	345	418	464	539	612	672	720	720

10 X 10 .020[illegible]" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices .50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	149	217	271	335	409	457	529	607	670	720	720
2	152	216	272	331	408	460	533	606	668	720	720
3	152	217	273	334	411	461	532	606	667	720	720
4	149	214	272	332	412	459	533	608	670	720	720
5	148	218	273	334	409	460	533	606	669	720	720
Total	750	1082	1361	1666	2049	2297	2660	3033	3344	-	-
Mean	150	216	272	333	410	459	532	607	669	720	720

14 X 14 .0200" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	141	203	253	319	385	427	491	569	621	679	720
2	142	205	253	320	385	426	492	569	620	683	720
3	140	207	254	320	384	427	490	572	621	682	720
4	142	205	253	319	387	427	492	568	623	679	720
5	143	204	252	317	384	425	492	571	620	682	720
Total	708	1024	1265	1596	1925	2132	2457	2849	3105	3405	-
Mean	142	205	253	319	385	426	491	570	621	681	720

30 X 30 .0095" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	119	180	231	297	359	405	468	544	593	651	720
2	121	180	230	296	359	406	470	546	595	650	720
3	121	179	230	297	358	404	468	544	595	652	720
4	118	183	229	298	357	406	469	547	596	650	720
5	120	183	230	296	359	406	470	545	595	652	720
Total	599	905	1150	1484	1792	2027	2345	2726	2974	3255	-
Mean	120	181	230	297	358	405	469	545	595	651	720

18 X 18 .0197" D. WIRE MESH

Test	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
No.	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	117	171	208	266	322	354	409	471	514	562	619
2	120	172	210	266	324	356	409	469	515	563	622
3	120	172	209	265	324	357	411	470	514	561	621
4	119	175	210	268	322	356	408	469	516	562	622
5	118	172	211	267	325	356	409	470	517	561	621
Total	594	862	1048	1332	1617	1779	2046	2349	2576	2807	3105
Mean	119	172	210	266	323	356	409	470	515	561	621

40 X 33 .0100" D. WIRE MESH

Test	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
No.	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	105	160	200	257	316	349	405	468	517	567	625
2	107	162	200	258	317	349	405	470	520	566	624
3	109	160	202	256	317	348	404	469	518	567	626
4	104	160	201	258	318	349	403	470	520	568	626
5	104	163	199	258	316	348	405	469	517	565	625
Total	529	805	1002	1287	1584	1743	2022	2346	2592	2833	3126
Mean	106	161	200	257	317	349	404	469	518	567	625

24 X 24 .0154" D. WIRE MESH

Test No.	Air Flow in Feet³ Per Feet² Per Minute Through Following Orifices										
	.50 in²	.75 in²	1.00 in²	1.25 in²	1.50 in²	1.75 in²	2.00 in²	2.25 in²	2.50 in²	2.75 in²	3.00 in²
1	103	153	188	241	294	325	374	433	471	517	572
2	103	155	188	241	297	325	375	433	472	518	573
3	105	153	192	239	296	327	375	434	470	517	572
4	105	152	189	242	297	324	376	435	472	517	572
5	106	153	189	242	295	325	373	433	471	519	574
Total	532	766	946	1205	1479	1626	1873	2168	2356	2588	2863
Mean	106	153	189	241	296	325	375	434	471	518	573

60 X 50 .0070" D. WIRE MESH

Test No.	Air Flow in Feet³ Per Feet² Per Minute Through Following Orifices										
	.50 in²	.75 in²	1.00 in²	1.25 in²	1.50 in²	1.75 in²	2.00 in²	2.25 in²	2.50 in²	2.75 in²	3.00 in²
1	88	136	172	220	271	303	345	401	441	479	533
2	89	137	173	221	270	303	347	402	442	482	531
3	89	134	172	220	272	305	347	402	443	482	531
4	87	134	171	220	272	302	347	403	443	480	530
5	88	137	173	223	271	303	345	402	444	481	531
Total	441	678	861	1104	1356	1516	1731	2010	2213	2404	2656
Mean	88	136	172	221	271	303	346	402	443	481	531

120 X 101 .0035" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	82	130	167	214	265	293	345	392	430	464	514
2	86	132	166	216	266	292	345	396	431	466	515
3	85	133	166	214	266	294	346	395	430	467	516
4	82	130	167	215	267	293	345	395	430	466	515
5	85	132	168	214	266	294	347	394	432	464	515
Total	420	657	834	1073	1330	1466	1728	1972	2153	2327	2575
Mean	84	132	167	215	266	293	346	394	431	465	515

90 X 76 .0050" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	81	125	158	200	250	280	320	369	400	437	495
2	82	124	157	201	252	281	322	371	405	435	493
3	79	127	157	201	252	280	321	371	403	437	492
4	79	127	158	200	250	281	320	369	403	437	495
5	80	124	160	200	250	281	320	369	402	434	494
Total	401	627	790	1002	1254	1403	1603	1849	2013	2180	2469
Mean	80	125	158	200	251	281	321	370	403	436	494

50 X 50 .0087" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	80	122	153	190	239	263	312	340	374	412	460
2	82	124	158	191	238	265	311	344	376	416	464
3	82	120	155	190	238	264	314	342	377	411	460
4	81	124	156	191	239	263	313	342	376	415	462
5	79	123	158	192	238	264	312	342	375	412	462
Total	404	613	780	954	1192	1319	1562	1710	1878	2066	2308
Mean	81	123	156	191	238	264	312	342	376	413	462

45 X 42 .0100" D. WIRE MESH

Test No.	Air Flow in Feet^3 Per Feet^2 Per Minute Through Following Orifices										
	.50 in^2	.75 in^2	1.00 in^2	1.25 in^2	1.50 in^2	1.75 in^2	2.00 in^2	2.25 in^2	2.50 in^2	2.75 in^2	3.00 in^2
1	78	123	163	192	236	260	313	345	374	409	462
2	78	120	163	194	234	262	313	340	370	406	460
3	80	121	164	193	234	261	314	343	372	409	463
4	81	120	163	194	236	262	314	342	372	410	462
5	80	123	164	192	236	261	314	343	371	410	463
Total	397	607	817	965	1176	1306	1568	1713	1859	2044	2310
Mean	79	121	163	193	235	261	314	343	372	409	462

SUMMARY OF RESULTS

		Area of Paper Orifice										
Wire Mesh	**% Air Space**	**.50**	**.75**	**1.00**	**1.25**	**1.50**	**1.75**	**2.00**	**2.25**	**2.50**	**2.75**	**3.00**
8 x 8 .0260"	62.37	164	232	284	345	418	464	539	612	672	720	720
10 x 10 .0205"	63.20	150	216	272	333	410	459	532	607	669	720	720
14 x 14 .0200"	51.84	142	205	253	319	385	426	491	570	621	681	720
30 x 30 .0095"	51.12	120	181	230	297	358	405	469	545	595	651	720
18 x 18 .0197"	41.01	119	172	210	266	323	356	409	470	515	561	621
40 x 33 .0100"	42.00	106	161	200	257	317	349	404	469	518	567	625
24 x 24 .0154"	39.74	106	153	189	241	296	325	375	434	471	518	573
60 x 50 .0070"	37.70	88	136	172	221	271	303	346	402	443	481	531
120 x 101 .0035"	37.50	84	132	167	215	266	293	346	394	431	465	515
90 x 76 .0050"	34.10	80	125	156	200	251	281	321	370	403	436	494
50 x 50 .0087"	31.92	81	123	156	191	238	264	312	342	376	413	462
45 x 42 .0100"	31.90	79	121	163	193	235	261	314	343	372	409	462

Sample Calculations for Per Cent Air Space

The following formula was developed for the calculation of per cent air space through the theoretical plane.

(1) Total Area - Area of Wire = Air Space Area

Letting total area = 1 square inch

(2) 1 in^2 - area of wire (in^2) = air space (in^2)

This air space can be expressed in % by simply multiplying by 100. To find the area of wire, use the ends and picks per inch in which case the formula will read

(3) $$\text{Air Space} = 1 - \left[(\text{Ends/inch})(\text{diam.wire}) + (\text{Picks/inch})(\text{diam.wire}) - (\text{Ends/inch})(\text{Picks/inch})(\text{diam.}^2)\right]$$

The (Ends/inch)(Picks/inch)(diam.^2) corrects for one of the two areas included at each wire intersection.

Using formula (3) to calculate %, Air Space of the 8 x 8, .0260" diam. wire mesh:

(3) $$1 - \left[(8)(.0260) + (8)(.0260) - (8)(8)(.0260)^2\right] =$$

$$1 - .3727 = 0.6273 \text{ or } 62.73\% \text{ Air Space}$$

Similar calculations were made on the other meshes.

Sample Calculations for Least Squares Equation

Using data for the 8 x 8 - .0260" Mesh - See plot Page

Air Flow Total (5 Tests) Y	Area Orifice (in^2 x 5) X		X^2	XY
818	(.5 x 5)	2.50	6.25	2,040
1,161	(.75 x 5	3.75	14.06	4,360
1,427	(1.00 x 5)	5.00	25.00	7,135
1,724	(1.25 x 5)	6.25	39.06	10,800
2,088	(1.50 x 5)	7.50	56.25	15,600
2,322	(1.75 x 5)	8.75	76.56	20,300
2,693	(2.00 x 5)	10.00	100.00	26,930
3,059	(2.25 x 5)	11.25	127.00	34,500
3,362	(2.50 x 5)	12.50	156.00	42,000

$\Sigma Y = 18{,}654$ $\quad \Sigma X = 67.50$ $\quad \Sigma X = 600.18$ $\quad \Sigma XY = 163{,}665$

$\Sigma Y = Na + b\Sigma X$ $\qquad \Sigma XY = a\Sigma X + b\Sigma X^2$

$18{,}654 = 45\,a + b\,67.5$ $\qquad 163{,}665 = a\,67.5 + b\,600.18$

$a = \dfrac{18{,}654 - 67.5\,b}{45} = a = \dfrac{163{,}665 - 600.18\,b}{67.5}$

$$\begin{aligned}
(67.5)(18{,}654 - 67.5\,b) &= (45)(163{,}665 - 600.18\,b)\\
1{,}260{,}000 - 4{,}550\,b &= 7{,}350{,}000 - 27{,}000\,b\\
27{,}000\,b - 4{,}550\,b &= 7{,}350{,}000 - 1{,}260{,}000\\
22{,}450\,b &= 6{,}090{,}000\\
b &= 271
\end{aligned}$$

$$\begin{aligned}
18{,}654 &= 45\,a + b\,67.5\\
a &= \frac{18{,}654 - (271)(67.5)}{45}\\
a &= \frac{18{,}654 - 18{,}200}{45}\\
a &= \frac{454}{45}\\
a &= 10.1
\end{aligned}$$

Straight line equation $y = a + bx$

Least squares equation $y = 10.1 + 271\,x$

Sample Calculations for Least Squares

Equation for plot on Page

Using data for 1 in^2 Orifice

	% Air Space X	Air Flow Y	X^2	Y^2	XY
8 x 8	62.73	281	3,950	78,961	17,600
10 x 10	63.20	273	3,994	74,529	17,250
14 x 14	51.84	254	2,690	64,516	13,180
30 x 30	51.12	237	2,620	56,169	12,130
18 x 18	41.01	210	1,690	44,100	8,620
40 x 33	42.00	206	1,764	42,436	8,650
24 x 24	39.74	191	1,580	36,481	7,590
60 x 50	37.70	176	1,421	30,976	6,640
120 x 101	37.50	171	1,406	29,241	6,410
90 x 76	34.10	162	1,163	26,244	5,520
50 x 50	31.92	154	1,020	23,716	4,920
45 x 42	31.90	154	1,018	23,716	4,880
No Space	0.00	0	0	0	0
	ΣX 524.76	ΣY 2,469	ΣX^2 24,316	ΣY^2 531,085	ΣXY 113,390

$$\Sigma Y = Na + b\Sigma X \qquad \Sigma XY = a\Sigma X + b\Sigma X^2$$

$$2469 = 13a + b524.76 \qquad 113{,}390 = a524.76 + b24{,}316$$

$$a = \frac{2469 - 524.76b}{13} = a = \frac{113{,}390 - 24{,}316b}{524.76}$$

$$(524.76)(2{,}469 - 524.76b) = (13)(113{,}390 - 24{,}316b)$$

$$1{,}293{,}000 - 275{,}000b = 1{,}474{,}070 - 316{,}108b$$

$$41{,}108b = 181{,}070$$

$$b = \underline{\underline{4.4}}$$

$$a = \frac{2{,}469 - (524.76)(4.4)}{13}$$

$$a = \frac{2{,}469 - 2308.944}{13}$$

$$a = \underline{\underline{12.3}}$$

$$y = a + bx$$

$$y = 12.3 + 4.4x$$

Similar calculations for 2 in^2 and 3 in^2 data.

Sample Calculations - Coefficient Correlation

Using data for 1 in^2 Orifice found on Page

$$\bar{X} = \frac{524.76}{13} = 40.4$$

$$\bar{Y} = \frac{2,469}{13} = 189.9$$

$$r = \frac{\Sigma XY - N\bar{X}\bar{Y}}{\sqrt{[(\Sigma X^2 - N\bar{X}^2)][(\Sigma Y^2 - N\bar{Y}^2)]}}$$

$$r = \frac{113,390 - (13)(40.4)(189.9)}{\sqrt{[(24,316 - (13)(40.4)^2][531,085 - (13)(189.9)^2]}}$$

$$r = \frac{113,390 - 99,735}{\sqrt{[24,316 - 21,218][531,085 - 468,806]}}$$

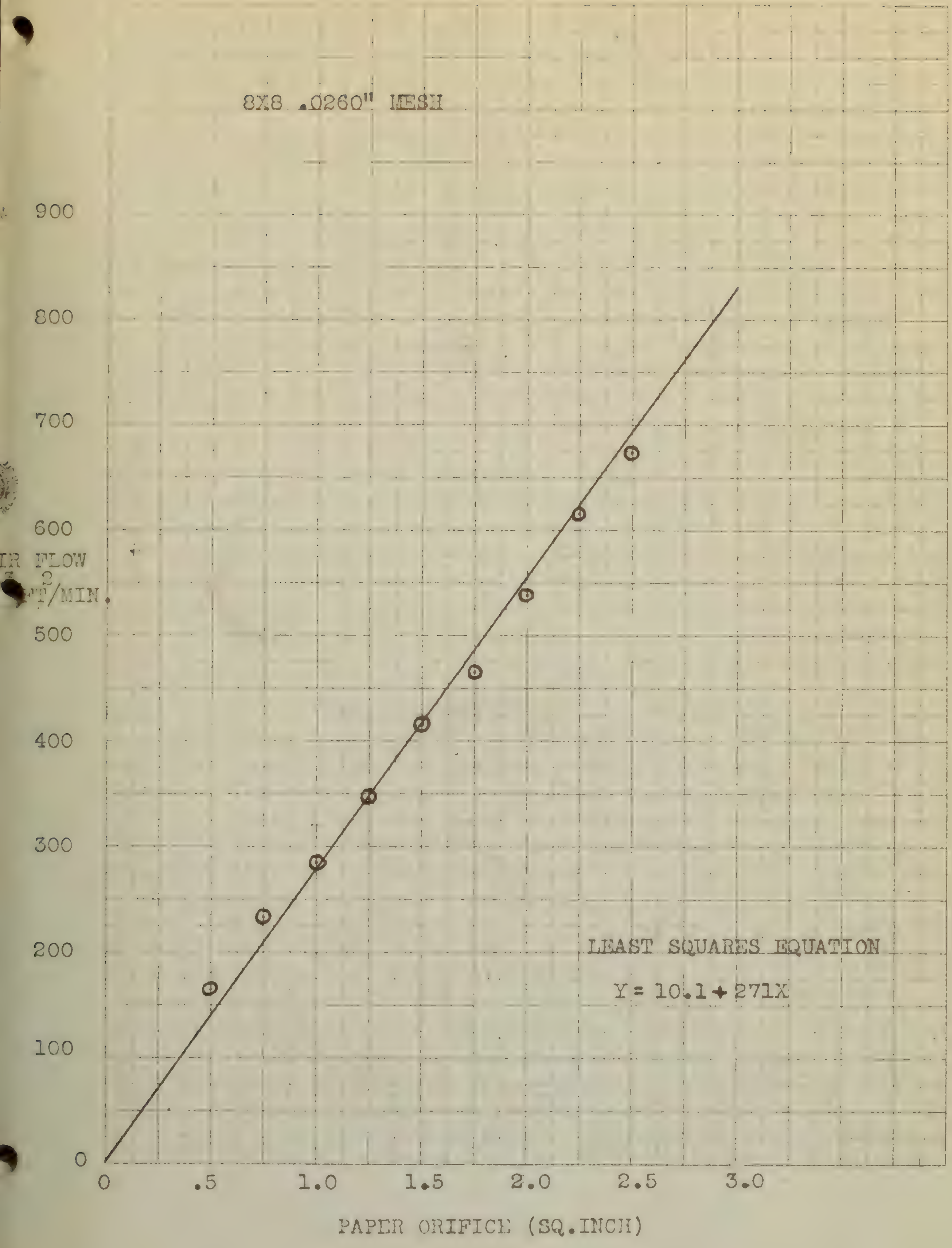
$$r = \frac{13,655}{\sqrt{[3098][62,279]}}$$

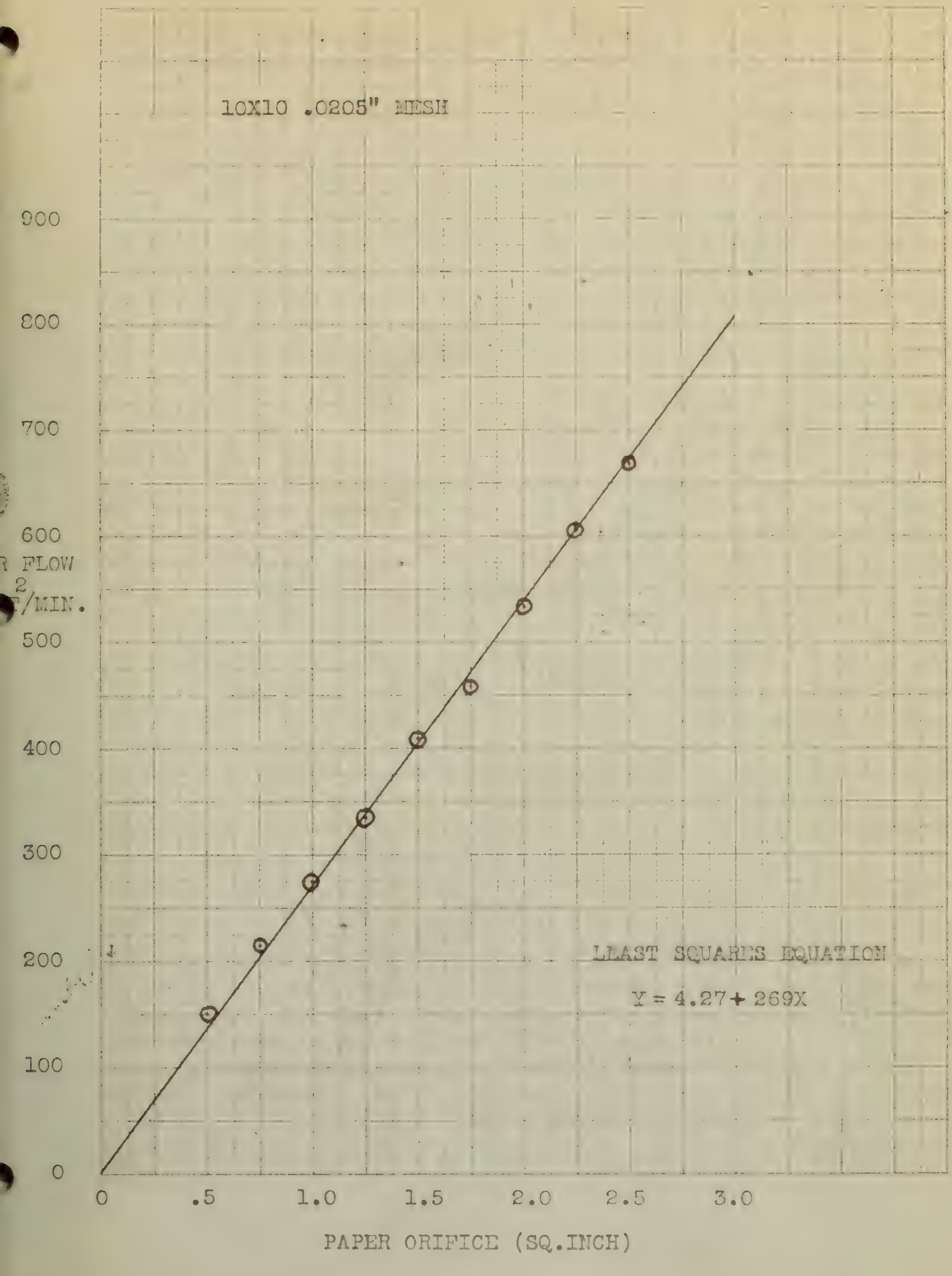
$$r = \frac{13,655}{\sqrt{192,940,342}}$$

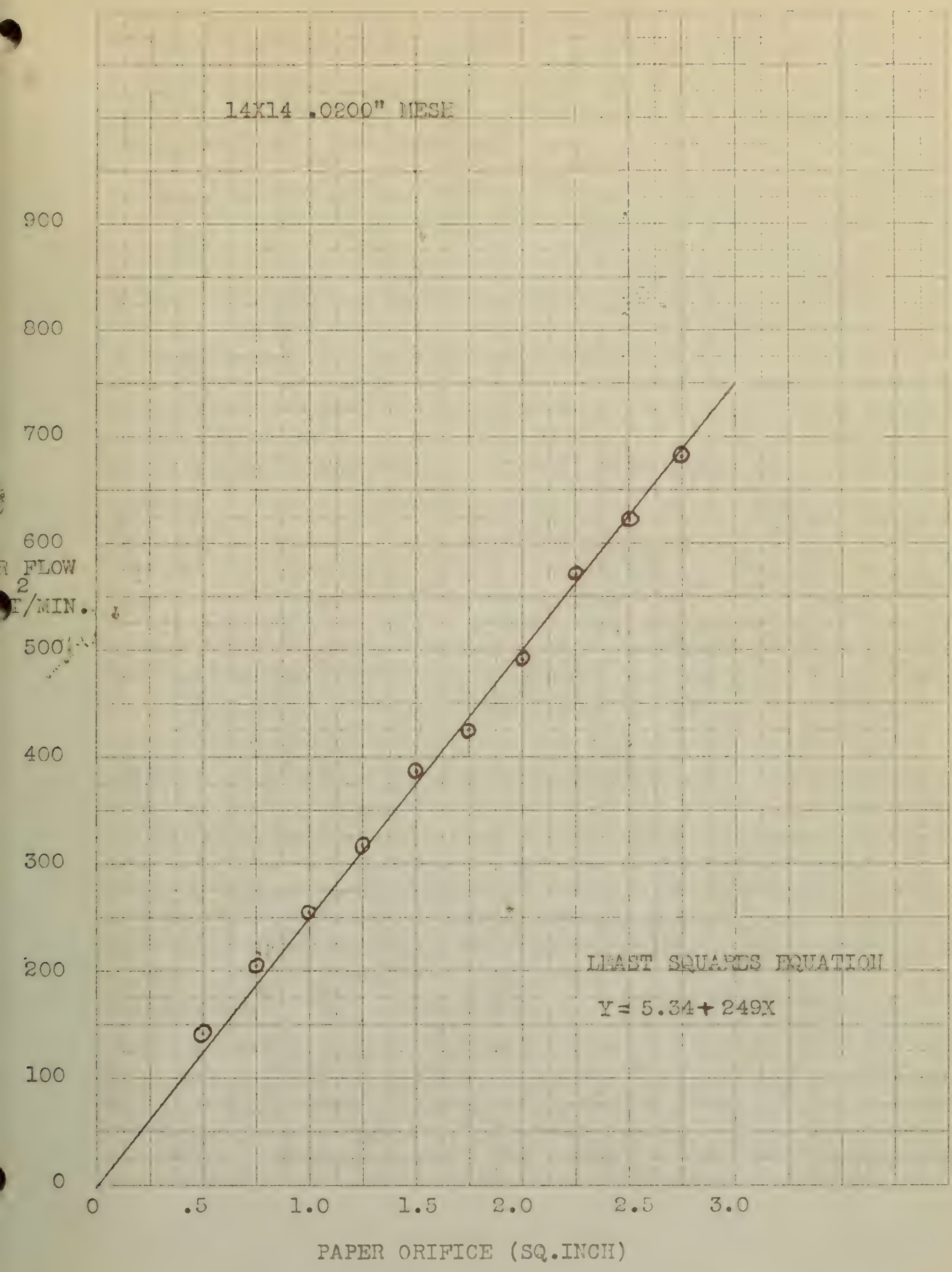
$$r = \frac{13,655}{13,890}$$

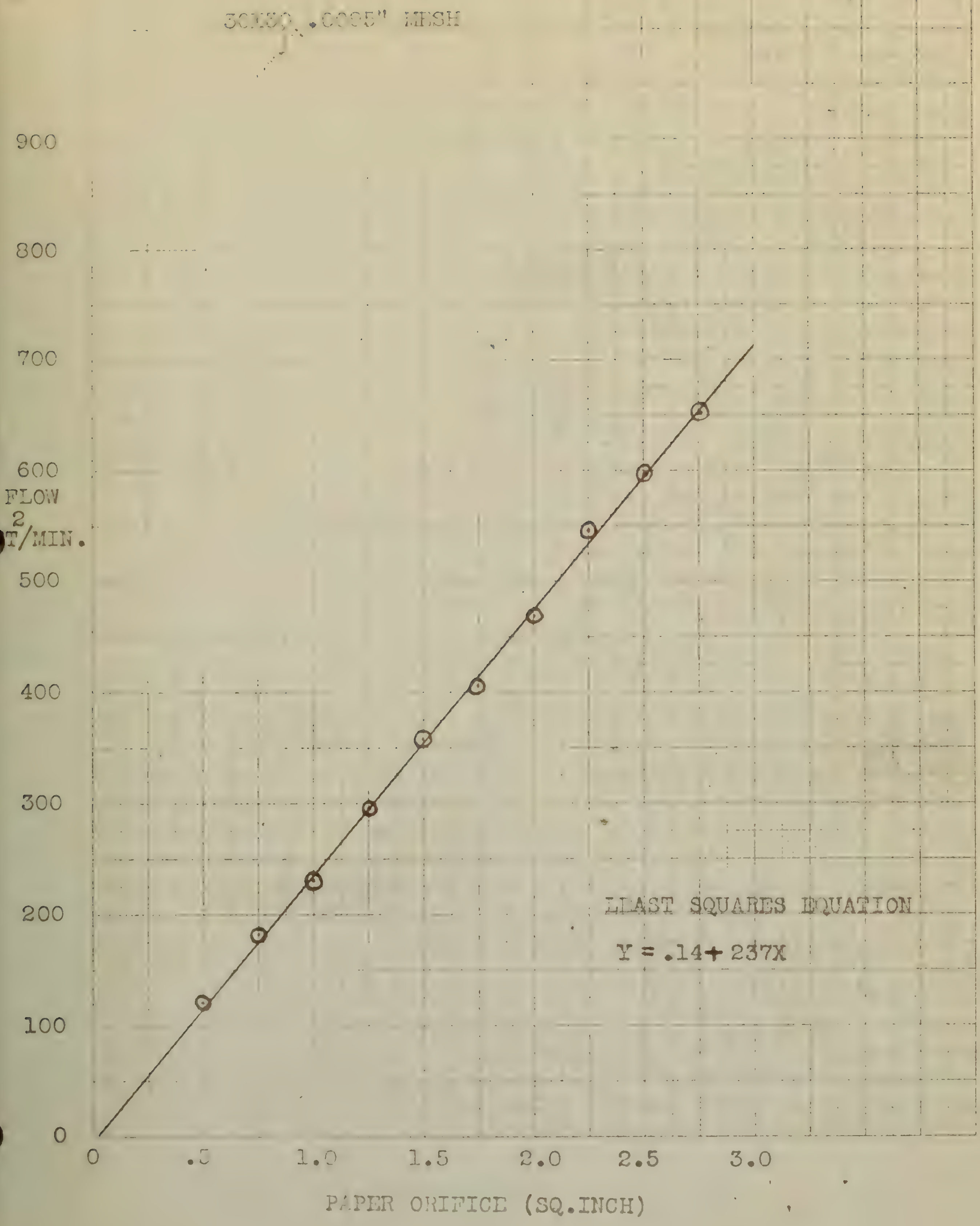
$$r = \underline{\underline{0.98}}$$

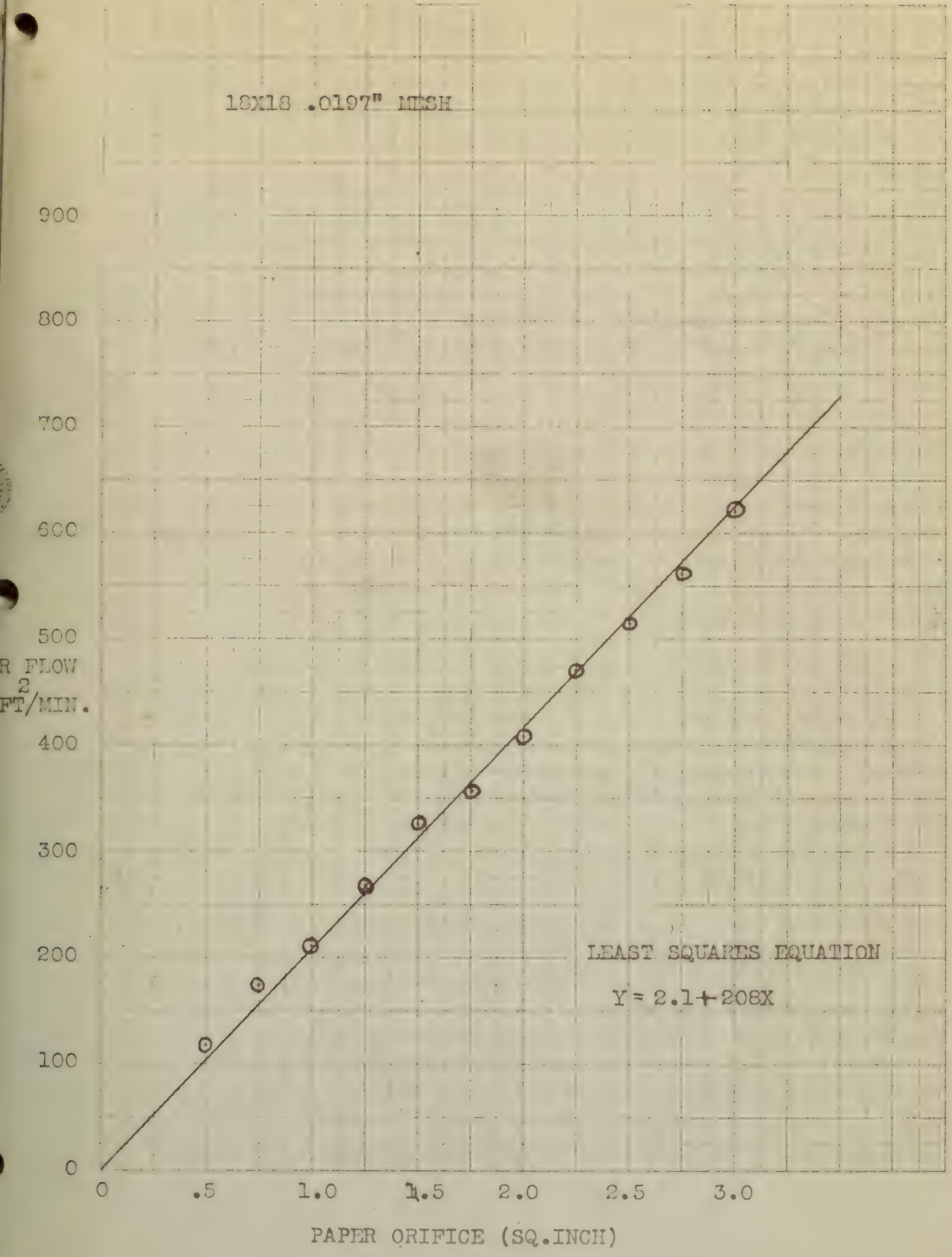
Similar calculations were made for the 2 in^2 and 3 in^2 Orifice data.

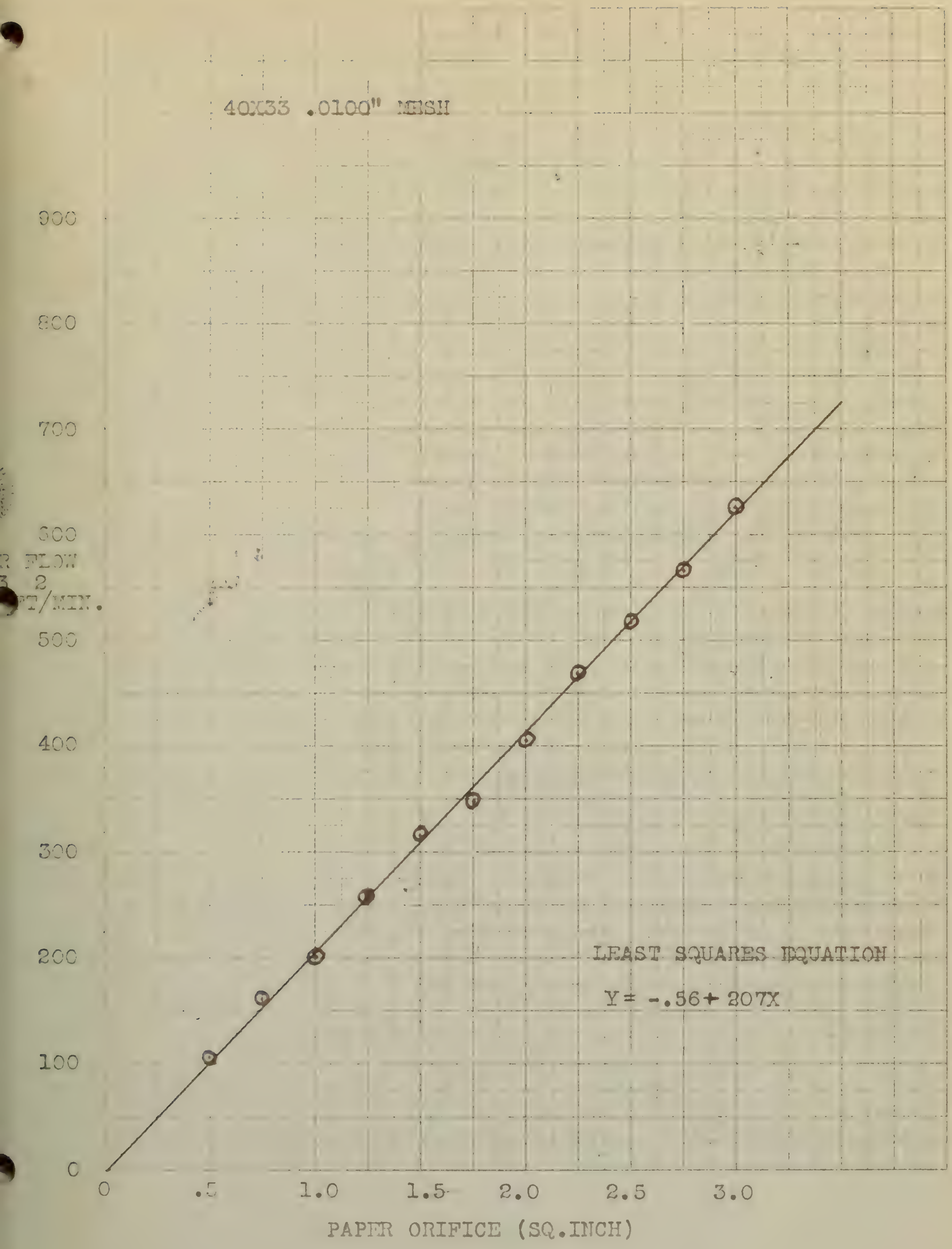

8X8 .0260" MESH
900
800
700
600
IR FLOW
T/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = 10.1 + 271X

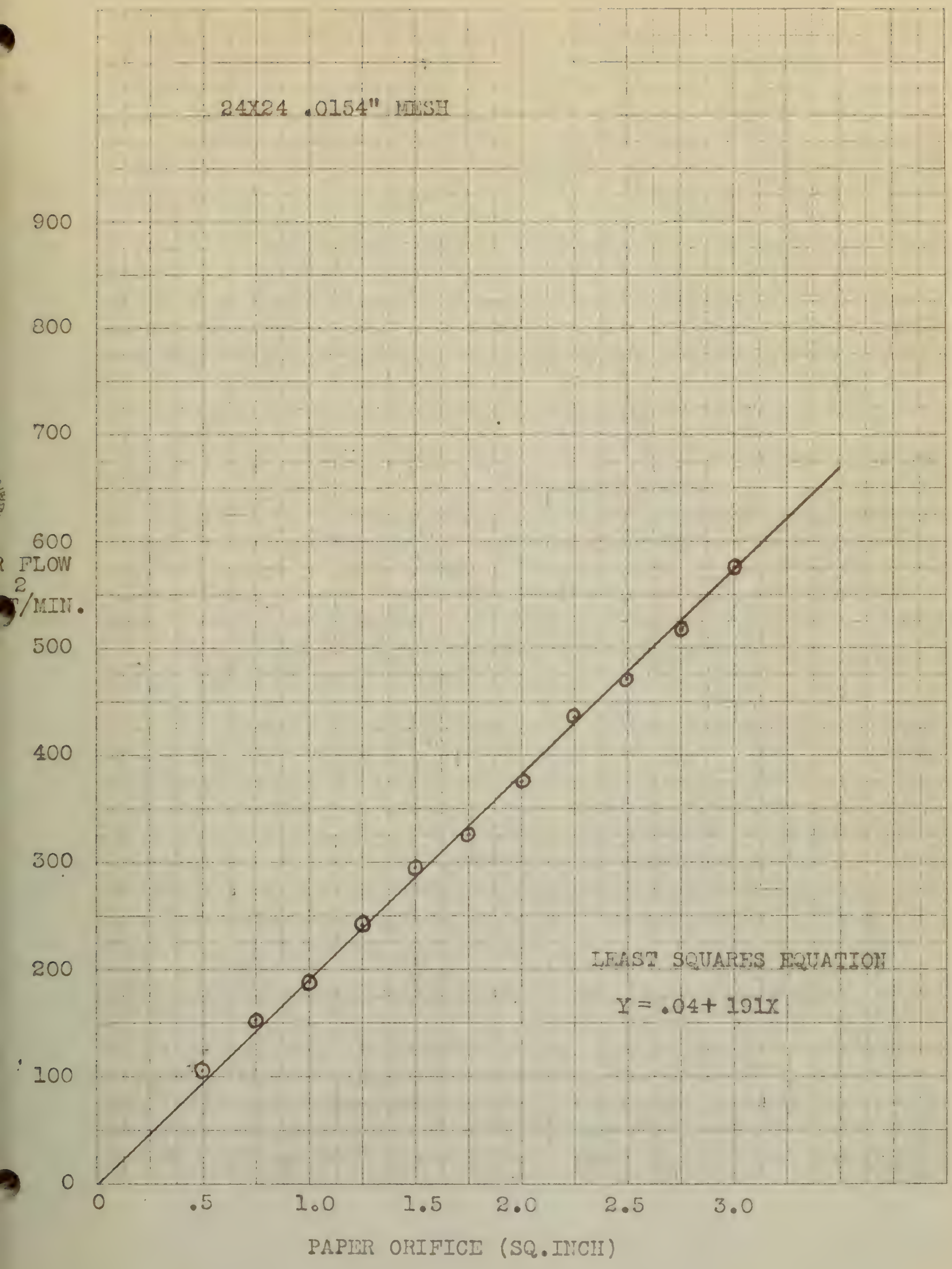

10X10 .0205" MESH
900
800
700
600
R FLOW
2
T/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = 4.27 + 269X

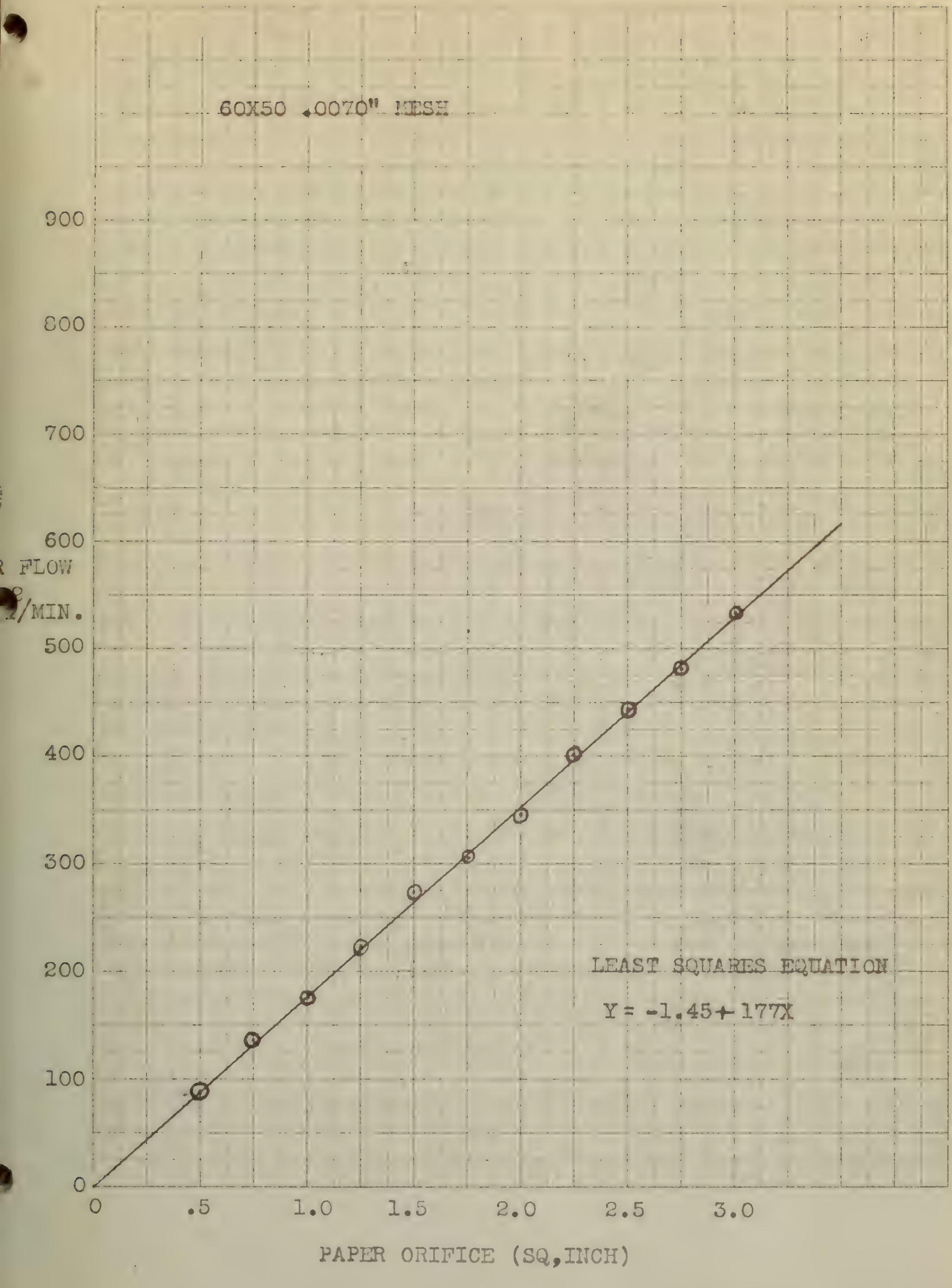

14X14 .0200" MESH
900
800
700
600
R FLOW
2
T/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = 5.34 + 249X

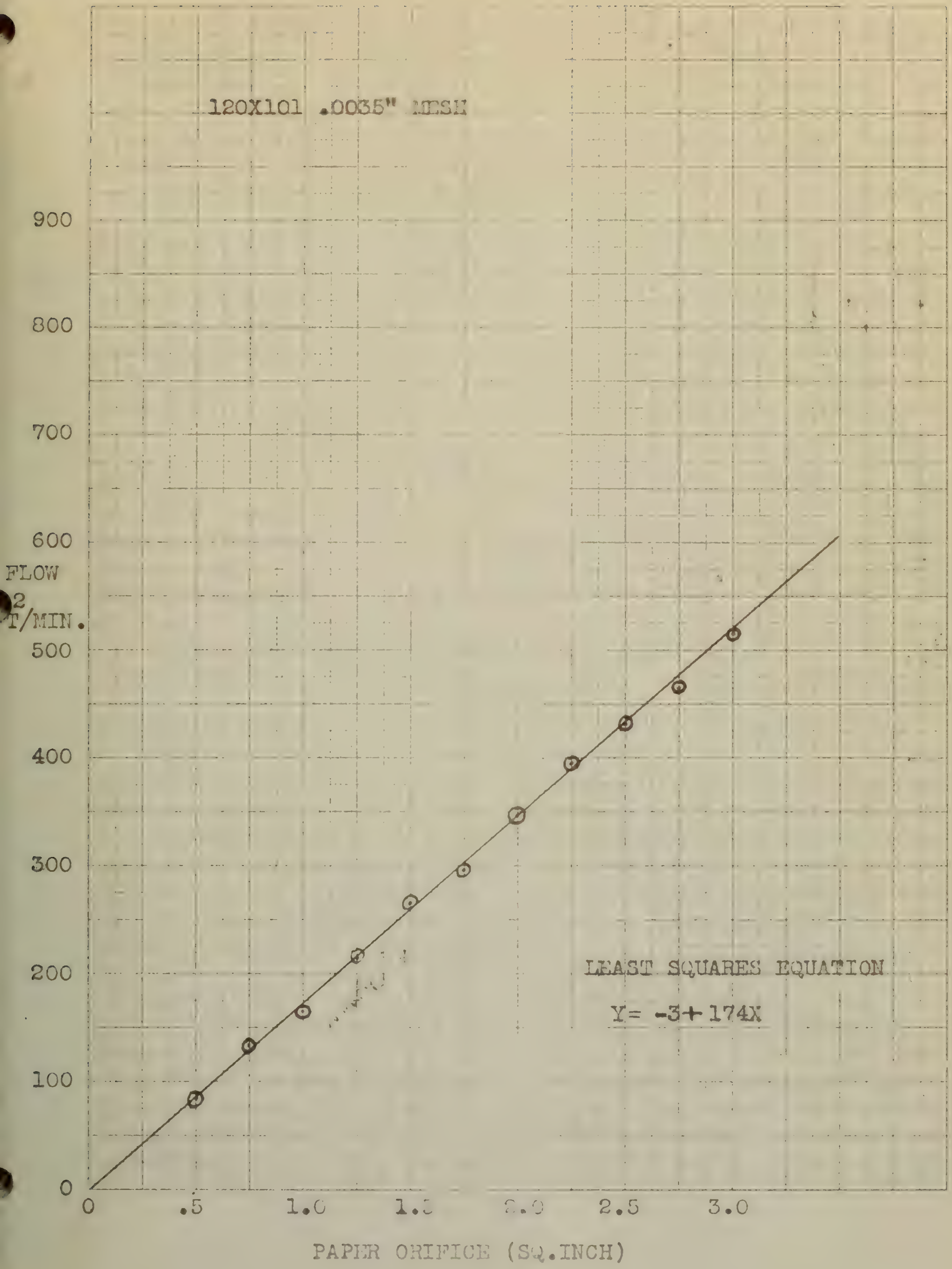

30X30 .0065" MESH
900
800
700
600
FLOW
2
T/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = .14 + 237X

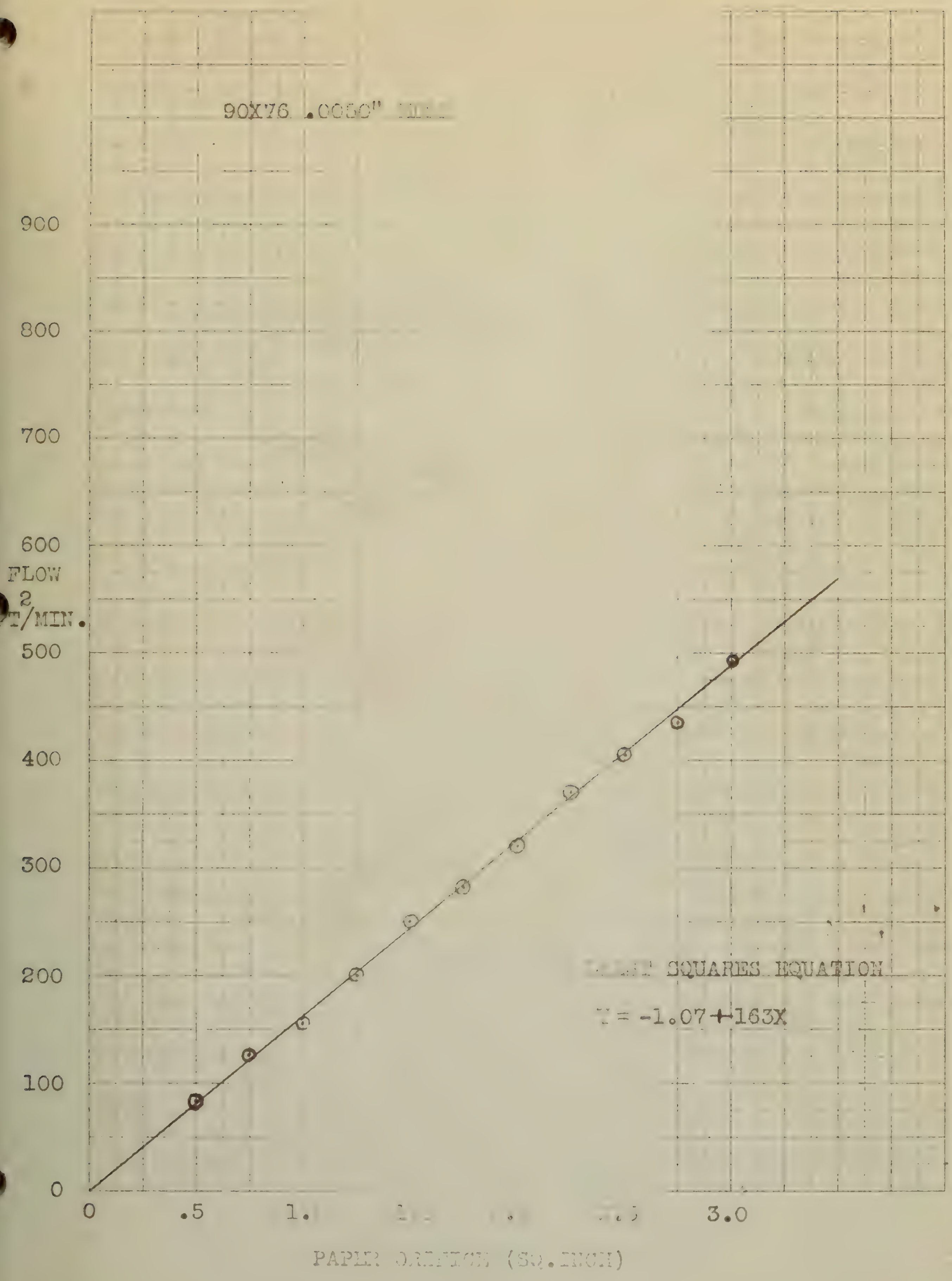

18X18 .0197" MESH
900
800
700
600
500
R FLOW
FT²/MIN.
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = 2.1+208X

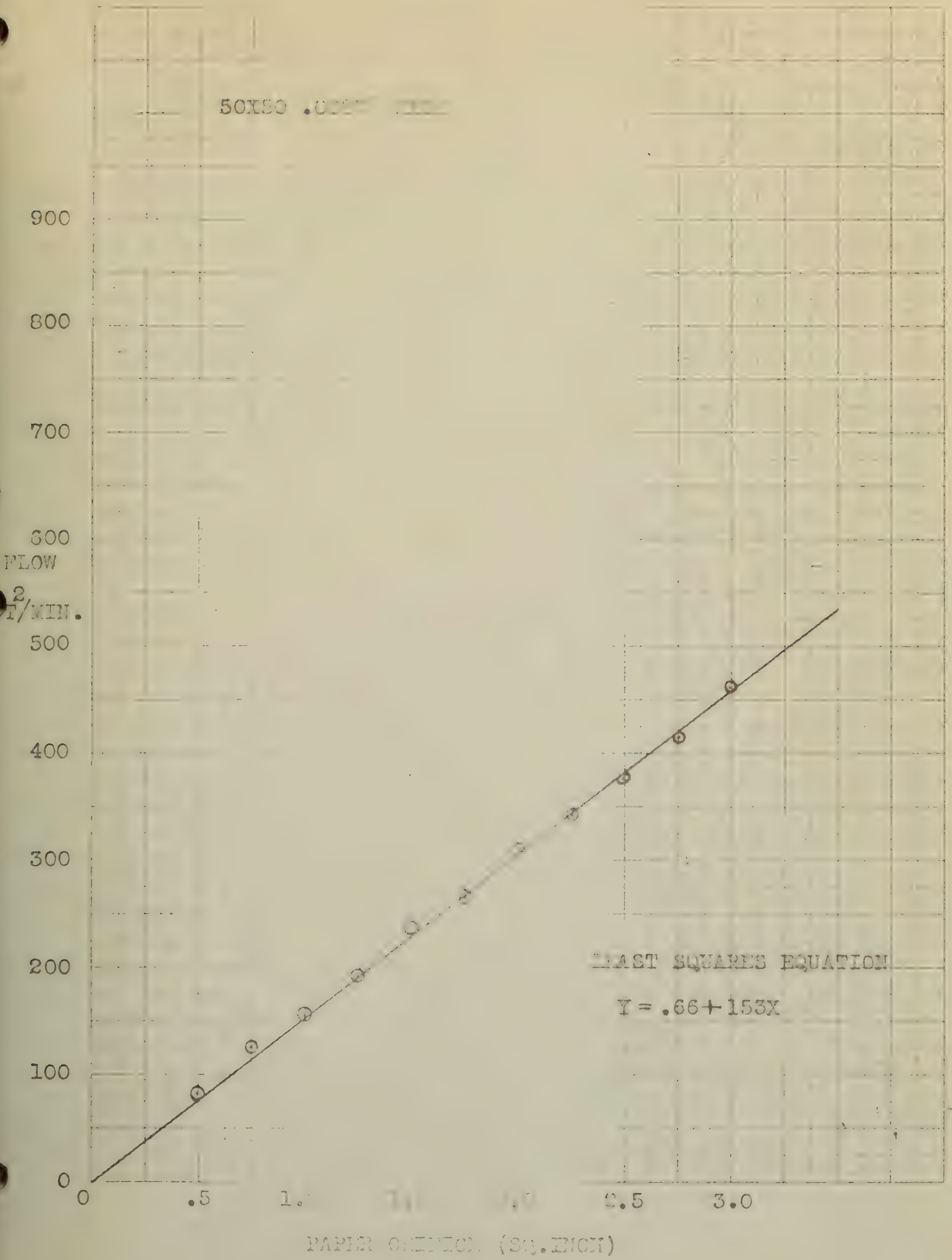

40X33 .0100" MESH
900
800
700
600
R FLOW
3 2
FT/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y= -.56+ 207X

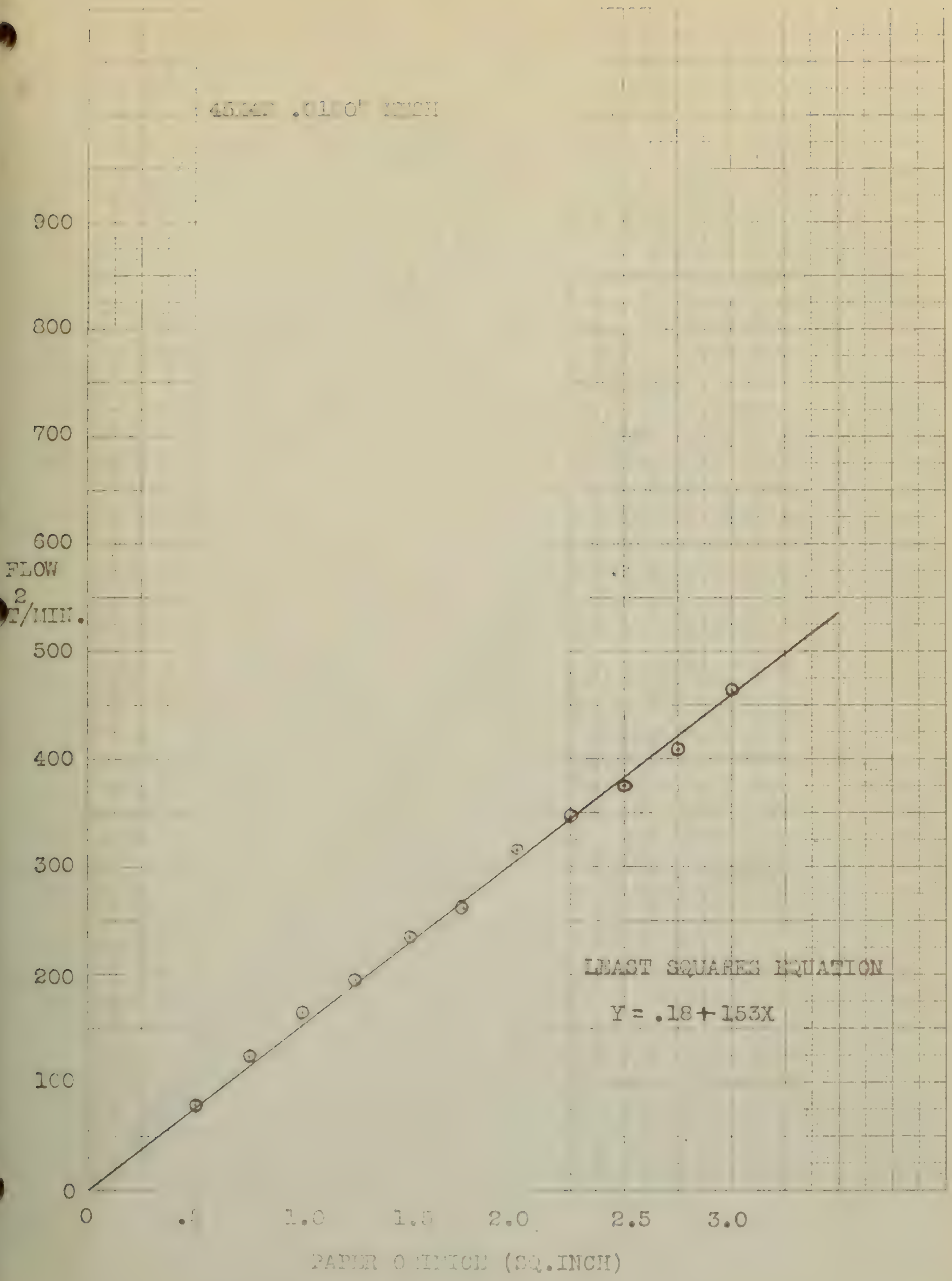

24X24 .0154" MESH
900
800
700
600
R FLOW
2
T/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = .04+ 191X

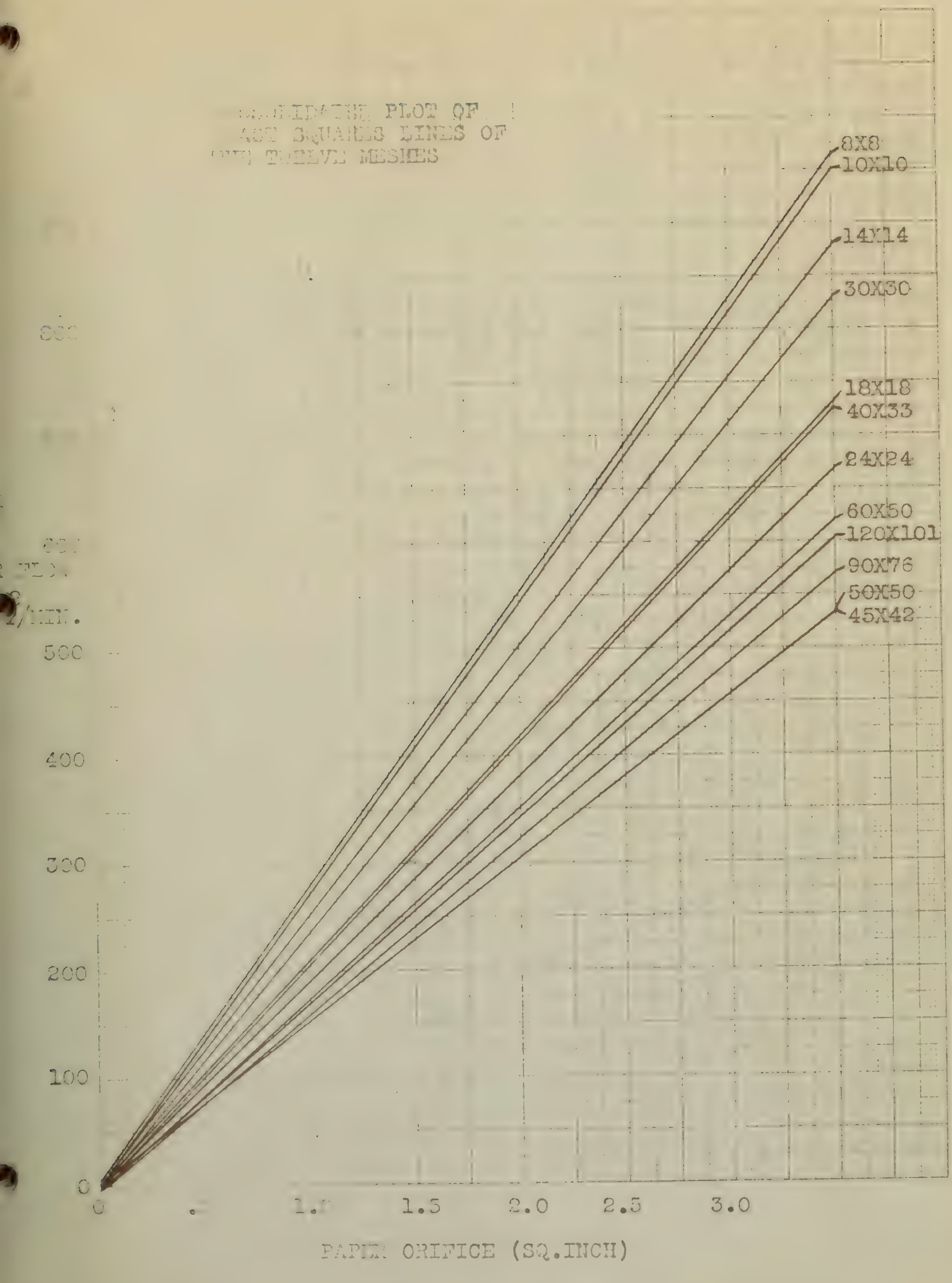

60X50 .0070" MESH
900
800
700
600
R FLOW
2
/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ,INCH)
LEAST SQUARES EQUATION
Y = -1.45 + 177X


120X101 .0035" MESH
900
800
700
600
500
400
300
200
100
0
FLOW
2
T/MIN.
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y= -3+174X

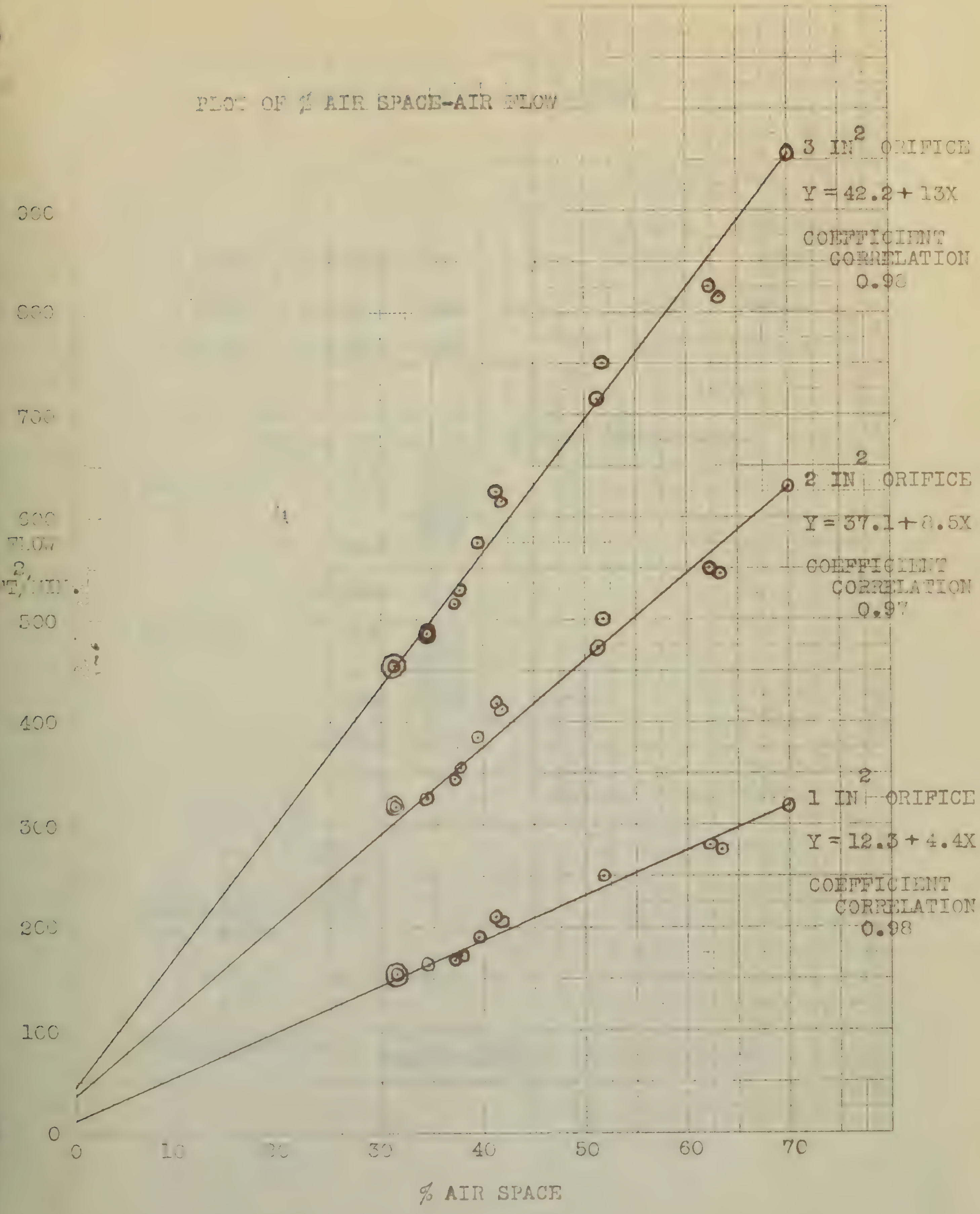

90X76 .0050" [illegible]
900
800
700
600
FLOW
2
T/MIN.
500
400
300
200
100
0
0
.5
1.
1.5
2.0
2.5
3.0
LEAST SQUARES EQUATION
Y = -1.07 + 163X
PAPER ORIFICE (SQ. INCH)


50X50 .0
900
800
700
600
FLOW
FT²/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (Sq.INCH)
LEAST SQUARES EQUATION
Y = .66+153X


45MAT .0100' MESH
900
800
700
600
FLOW
FT²/MIN.
500
400
300
200
100
0
0
.5
1.0
1.5
2.0
2.5
3.0
PAPER ORIFICE (SQ.INCH)
LEAST SQUARES EQUATION
Y = .18 + 153X



CONSOLIDATED PLOT OF LEAST SQUARES LINES OF THE TWELVE MESHES


PLOT OF % AIR SPACE-AIR FLOW
3 IN^2 ORIFICE
Y = 42.2 + 13X
COEFFICIENT CORRELATION 0.98
2 IN^2 ORIFICE
Y = 37.1 + 8.5X
COEFFICIENT CORRELATION 0.97
1 IN^2 ORIFICE
Y = 12.3 + 4.4X
COEFFICIENT CORRELATION 0.98
R FLOW
FT^3/MIN.
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
% AIR SPACE

Calculations for Average Equation

For		If X = 0 Y =	If X = 70 Y =
3 in^2	$y = 42.2 + 13x$	42.2	952.2
2 in^2	$y = 37.1 + 8.5x$	37.1	632.1
1 in^2	$y = 12.3 + 4.4x$	12.3	320.3

Dividing Y values by 3, 2, and 1 respectively

For X = 0	Y =	14.1
		18.6
		12.3
	Total	45.0
	Average	15.0
For X = 70	Y =	317.4
		316.1
		320.3
	Total	953.8
	Average	317.9

$$y = a + bx$$

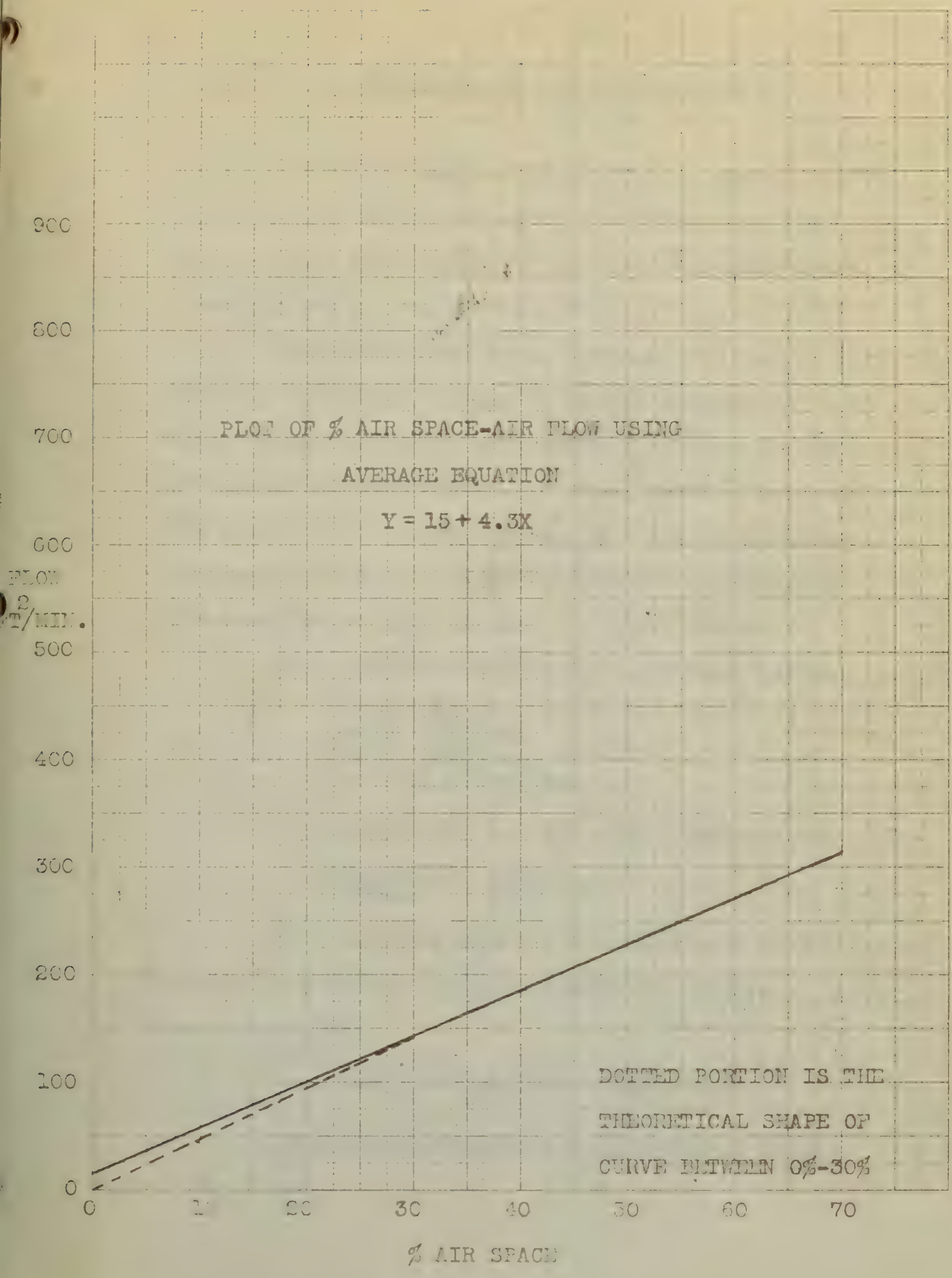
$$15 = a + (b)(0)$$

$$\underline{317.9 = a + (b)(70)}$$

$$302.9 = 70b$$

$$b = 4.3 \qquad a = 15$$

Average Equation: $\underline{\underline{y = 15 + 4.3x}}$



PLOT OF % AIR SPACE-AIR FLOW USING

AVERAGE EQUATION

$Y = 15 + 4.3X$

DOTTED PORTION IS THE

THEORETICAL SHAPE OF

CURVE BETWEEN 0%-30%

DISCUSSION AND CONCLUSIONS - PHASE I

The average equation derived from the plot on Page 38 ($y = 15 + 4.3\,x$) can be used as the theoretical formula for the flow of air through wire mesh having a range of air space between 30% and 70% with great accuracy.

Assume the calculated % air space to be 41%. (Referring to the plot on Page 38, the 41% value has the highest deviation from the least squares line and would represent the maximum error for the mesh being tested.) The actual flow value for 1 in^2 orifice of this 41% air space mesh, taken from the plot on Page 38 is 210 ft^3/ft^2/min. The theoretical flow taken from the plot on Page 40 is 191 ft^3/ft^2/min.

Using the theoretical average equation as a check:

$$\begin{aligned} y &= 15 + 4.3\,x \\ y &= 15 + (4.3)(41) \\ y &= 15 + 176.1 \\ y &= 191.1 \text{ ft}^3/\text{ft}^2/\text{min.} \end{aligned}$$

The per cent error for this maximum deviation is:

$$\frac{210 - 191.1}{191.1} = \frac{18.9}{191.1} = 9.9\%$$

The actual flow value for 2 in^2 orifice on the 41% air space mesh is 415. The theoretical value would be 2 x 191.1 or 382.2.

$$\% \text{ Error} = \frac{415 - 382.2}{382.2} = \frac{32.8}{382.2} = 8.6\%$$

The actual flow value for 3 in^2 orifice on the 41%

air space mesh is 625. The theoretical value would be $3 \times 191.3 = 573.3$.

$$\% \text{ Error} = \frac{625 - 573.3}{573.3} = \frac{51.7}{573.3} = 9.0\%$$

Taking the average % error it is found that the maximum error based on actual test conditions is 9.17%. As stated before, this represents the maximum possible deviation, and as supported by the coefficients of correlation of 0.98, 0.97, and 0.98 for the 1 in^2, 2 in^2, and 3 in^2 orifices plotted on Page 38, the chances of error being of this magnitude are slight.

Since most fabrics would not have more than 70% air space it is not necessary to predict the slope of the curve of plot on Page 40 beyond the 70% point. However, there are many fabrics that will fall in the range from 0 to 30% air space. Looking at plot on Page 40, the derived average equation line cuts the Y-axis at 15. Actually, the flow at 0% air space must be 0. Thus, for theoretical calculations of air flow, the dotted portion of the curve from 0% to 30% air space has been used. As shown, the deviation from the average equation line is slight.

In summing up the conclusions of Phase I, it is now possible to predict within very slight error the flow of air through wire mesh ranging from 0% to 70% air space. It is proposed to apply this basic equation and the plot on Page 40 to various fabrics in Phase II.

PHASE II

INTRODUCTION

As explained in the Theory on Page 6, an accurate method of calculating air space through the theoretical plane of the fabric is necessary. On Page 21 is given the formula used to calculate this air space for wire mesh. Its use is most valuable as applied to wire mesh, since the diameter of the wire in the theoretical plane is the actual wire diameter as measured by a set of calipers. However, when passing from wire mesh to fabric, it is obvious that the diameters of the ends and picks lying in the theoretical plane of the fabric may be greater than the diameters set up in the loom. There may be a flattening out effect which would reduce air space. There may be some coating put on the yarn to increase its size or some finishing or pressing process may have altered the effective area of interstics.

Therefore, it was necessary to devise some method of calculating effective area in the theoretical plane for fabrics. The projection of a magnified image of the fabric upon a screen was decided upon for this purpose, with a magnification of 250. It was found that this magnification gave a clear cut picture of the actual amount of air space in the theoretical plane when the fabrics were projected onto the screen.

The calculation of air space can be approached in one of two ways, either by taking the average diameter of the ends and picks as seen under 250 magnification and using the formula developed for wire mesh, or by determining the areas of interstices themselves, as seen upon projection. The air passing through the fabric is permitted to pass only through the interstices shown under magnification, providing that the ends and picks are solid enough in construction to show up as a solid cylinder under 250 magnification. This restriction precludes the possibility of air passing through the yarn itself. In addition to this restriction, it was necessary to select fabrics whose interstices had some semblance of uniformity and regularity in order to get an accurate measure of air space through the theoretical plane.

MATERIAL

The second phase of testing was done on seven fabrics selected under the restrictions discussed in the Introduction on Page 44. No attempt was made to determine the type of yarn, or weave, or finish, or any other physical aspect of the fabric. If the ends and picks appeared solid under 250 magnification and the interstices were regular and uniform, the fabric was put to the test. Listed below are the seven fabrics selected, with number of ends and picks per inch being the only identifying characteristic:

Fabric	Ends/Inch	Picks/Inch
1	69	78
2	74	90
3	76	120
4	62	74
5	51	45
6	27	26
7	24	22

APPARATUS

The air permeability machine was again used in Phase II of this thesis. In addition, the projection microscope with a magnification of 250 was used. The eye piece or ocular was 10X and the objective lens was 12.5X. By properly adjusting the distance from the microscope to the screen upon which the image was projected, it was possible to arrive at the 250 magnification. The lighting was incident light from a 500 watt micro-illuminator. The screen upon which the image was projected was graph paper with ten spaces to the inch, from which readings in tenths of inches could be read directly.

PROCEDURE

To verify the soundness of the use of the projection system and to further support the correctness of the air space formula as applied to the wire mesh, several of the wire meshes were first tested under projection to obtain % air space. Five meshes were projected under the 250 magnification, the diameters of ends and picks, and the lengths and widths of interstices were measured (data on Pages 49 and 50). The % air space was then calculated (see Page 54) and this % air space was then compared with that found in Phase I (Page 57).

After verification of the use of the projection method (see Page 57), the next step was to place each of the seven fabrics under the projection apparatus. Since the air space was so small compared to the size of the ends and picks, and since the field of vision was limited, the diameter of the yarns of fabric #1 only could be measured. In addition, the lengths and widths of interstices of fabric #1 were measured. This data appears on Page 51. For fabrics 2 through 7, lengths and widths of interstices only were measured. Each reading was taken with the fabric in a new position. These data appear on Pages 52 and 53. The % air space for each of the seven fabrics was calculated as shown on Page 54.

After calculating the % air space for the seven fabrics, the air flow was measured by placing each fabric on the air permeability machine and obtaining air flow at 0.5 inch drop by using four paper orifice openings, 1 in^2, 2 in^2, 3 in^2, and 5.94 in^2. The air flow data for each of the fabrics appears in the Summary of Data on Page 55. A plot of the air flow versus paper orifice opening data (Page 55) was constructed for each fabric on the consolidated plot of Page 56.

DATA

Wire Mesh - Projection Method

	Interstice		
60 x 50 .0070" Wire	Magnified Length "	Magnified Width "	Magnified Diameter "
1	2.7	3.2	1.7
2	2.3	3.3	1.8
3	2.4	3.2	1.8
4	2.6	2.9	1.7
5	2.7	3.0	1.7
6	2.2	3.4	1.7
7	2.4	3.1	1.8
8	2.4	2.8	1.8
9	2.4	2.8	1.7
10	2.6	3.3	1.7
11	2.4	3.3	1.8
12	2.5	2.9	1.8
13	2.2	2.8	1.8
14	2.2	3.1	1.7
15	2.6	3.3	1.6
16	2.5	3.3	1.7
17	2.5	2.9	1.8
18	2.7	3.2	1.9
19	2.3	3.4	1.8
20	2.2	2.9	1.7
TOTAL	48.8	62.1	35.0
AVERAGE	2.44"	3.11"	1.75"
ACTUAL VALUES	$\frac{2.44}{250} = .0098''$	$\frac{3.11}{250} = .0124''$	$\frac{1.75}{250} = .0070''$

Wire Mesh - Projection Method

	Magnified Length "	Magnified Width "	Magnified Diameter "
30 x 30 .0095" Wire			
AVERAGE	6.01"	6.09"	2.33"
ACTUAL VALUES	$\frac{6.01}{250}$ = .024"	$\frac{6.09}{250}$ = .024"	$\frac{2.33}{250}$ = .0093"
18 x 18 .0197" Wire			
AVERAGE	9.00"	9.00"	4.87"
ACTUAL VALUES	$\frac{9.00}{250}$ = .036"	$\frac{9.00}{250}$ = .036"	$\frac{4.87}{250}$ = .0195"
24 x 24 .014" Wire			
AVERAGE	6.2"	7.0"	3.87"
ACTUAL VALUES	$\frac{6.2}{250}$ = .0248"	$\frac{7.0}{250}$ = .028"	$\frac{3.87}{250}$ = .0155"
120 x 101 .0035" Wire			
AVERAGE	1.18"	1.68"	0.85"
ACTUAL VALUES	$\frac{1.18}{250}$ = .0047"	$\frac{1.68}{250}$ = .0067"	$\frac{0.85}{250}$ = .0034"

Fabrics - Projection Method

Fabric #1 69 x 78	Interstice Magnified Length "	Interstice Magnified Width "	Magnified Diameter "
1	2.8	2.0	1.3
2	2.6	2.1	1.4
3	2.2	2.1	1.3
4	2.3	2.0	1.4
5	2.7	1.7	1.0
6	2.3	1.8	1.1
7	2.6	1.7	1.5
8	2.4	2.3	1.1
9	2.9	1.7	1.3
10	1.9	2.1	1.5
11	2.4	2.0	1.4
12	2.1	1.8	1.2
13	2.8	1.7	1.5
14	2.3	1.7	1.0
15	2.2	1.8	1.0
16	2.8	1.8	1.3
17	2.8	1.6	1.2
18	2.0	2.1	1.3
19	2.0	1.9	1.5
20	2.5	1.8	1.1
21	2.9	2.0	1.2
22	3.0	2.1	1.1
23	3.0	2.1	1.5
24	2.4	2.2	1.4
25	2.4	2.0	1.3
26	2.6	1.8	1.2
27	2.6	1.9	1.4
28	2.5	2.0	1.3
29	2.5	2.3	1.2
30	2.2	2.0	1.5
31	2.1	1.9	1.0
32	2.2	1.7	1.1
33	2.3	1.9	1.5
34	2.3	2.3	1.2
35	2.0	2.2	1.4
36	2.5	2.0	1.3
37	2.3	1.8	1.0
38	1.9	1.7	1.1
39	1.9	1.9	1.2
40	2.0	2.0	1.3
TOTALS	96.2	77.5	50.6
AVERAGE	2.405	1.9375	1.265
ACTUAL VALUE	$\frac{2.405}{250}$ =.00962"	$\frac{1.9375}{250}$ =.00775"	$\frac{1.265}{250}$ =.0051"

Fabrics - Projection Method

	Fabric #2	74 x 90	Fabric #3	76 x 120	Fabric #4	62 x 74
Readings	Magnified Length "	Interstices Width "	Magnified Length "	Interstices Width "	Magnified Length "	Interstices Width "
1	1.6	1.4	0.8	0.3	1.2	0.9
2	2.0	1.3	0.8	0.3	1.2	0.6
3	1.9	1.4	1.1	0.2	1.3	0.8
4	1.5	1.3	0.8	0.4	1.2	0.7
5	1.6	1.5	0.9	0.4	1.2	0.7
6	1.6	1.4	1.0	0.3	1.2	0.5
7	1.7	1.6	0.9	0.3	1.0	0.8
8	1.6	1.3	0.7	0.2	1.1	0.7
9	1.6	1.2	0.8	0.2	1.3	0.6
10	1.6	1.4	0.7	0.3	1.0	0.6
11	1.4	1.4	0.9	0.2	1.1	0.9
12	2.0	1.3	0.6	0.2	1.0	0.5
13	1.7	1.3	0.6	0.3	1.0	0.8
14	1.1	1.3	0.5	0.4	1.0	0.7
15	1.3	1.7	0.9	0.3	1.1	0.4
16	2.3	1.4	0.6	0.4	1.2	0.6
17	2.0	1.4	0.9	0.3	1.2	0.8
18	2.0	1.5	0.6	0.3	1.2	0.7
19	2.0	1.3	0.5	0.3	1.1	0.6
20	1.7	1.2	0.7	0.3	1.2	0.6
21	1.5	1.5	0.9	0.3	1.2	0.6
22	1.5	1.4	0.8	0.4	1.2	0.7
23	2.1	1.5	0.7	0.2	1.1	0.5
24	1.7	1.2	0.7	0.2	1.0	0.7
25	2.0	1.1	0.9	0.3	1.0	0.6
26	1.9	1.4	0.6	0.3	1.0	0.5
27	1.6	1.4	0.7	0.4	1.2	0.7
28	2.0	1.5	0.8	0.3	1.2	0.6
29	1.4	2.0	1.0	0.3	1.3	0.7
30	1.6	1.4	0.7	0.2	1.2	0.6
31	2.1	1.6	0.9	0.3	1.0	0.7
32	2.1	1.7	1.0	0.4	1.3	0.9
33	1.8	1.5	0.8	0.1	1.1	0.8
34	2.4	1.6	0.7	0.3	1.0	0.7
35	2.0	1.4	0.7	0.2	1.1	0.5
36	2.1	1.6	0.8	0.3	1.2	0.7
37	2.0	1.7	0.6	0.3	1.1	0.6
38	2.2	1.6	0.8	0.2	1.2	0.5
39	2.0	1.8	0.7	0.3	1.0	0.7
40	2.0	1.7	0.6	0.3	1.2	0.7
TOTALS	72.2	58.2	30.7	11.5	45.4	27.0
AVERAGE	1.805	1.455	.7725	.2875	1.135	0.675
ACTUAL VALUE	$\frac{1.805}{250} =$	$\frac{1.455}{250} =$	$\frac{.7725}{250} =$	$\frac{.2875}{250} =$	$\frac{1.135}{250} =$	$\frac{0.675}{250} =$
	.00722	.00582	.00309	.00115	.00454	.0027

Fabrics - Projection Method

Readings	Fabric #5 Magnified Length "	51 x 45 Interstices Width "	Fabric #6 Magnified Length "	27 x 26 Interstices Width "	Fabric #7 Magnified Length "	24 x 22 Interstices Width "
1	1.0	.8	7.3	7.0	8.2	7.3
2	1.5	.9	7.0	6.6	7.9	7.5
3	1.4	.8	6.9	6.6	7.9	7.1
4	1.4	.7	7.2	6.7	8.3	7.0
5	1.3	.8	7.3	7.0	8.2	7.5
6	1.2	.9	7.0	6.8	7.8	7.4
7	1.5	.6	6.8	6.5	7.7	7.3
8	1.4	.9	6.9	6.7	8.3	7.2
9	1.3	.8	6.9	6.6	7.9	7.4
10	1.2	.7	6.8	6.5	7.8	7.0
11	1.2	.8	7.2	7.0	7.7	7.5
12	1.5	.9	7.3	6.4	7.9	7.1
13	1.2	.7	7.4	6.5	8.0	7.4
14	1.4	.6	7.3	6.9	8.1	7.3
15	1.3	.6	7.1	6.9	8.0	7.4
16	1.2	.7	7.0	6.7	7.9	7.5
17	1.5	.8	7.1	6.7	8.2	7.4
18	1.4	.7	7.0	6.9	8.2	7.3
19	1.2	.8	6.9	7.0	7.8	7.2
20	1.2	.9	6.8	6.6	7.8	7.5
21	1.3	.6	6.9	6.5	7.9	7.1
22	1.3	.7	7.2	6.6	8.0	7.0
23	1.5	.8	7.2	6.9	7.7	7.2
24	1.1	.9	7.3	6.8	7.9	7.4
25	1.3	.8	7.0	6.7	8.2	7.5
26	1.3	.8	6.8	6.7	8.0	7.0
27	1.4	.7	7.1	6.9	7.9	7.3
28	1.5	.7	6.9	7.0	8.2	7.5
29	1.4	.6	6.8	7.0	8.0	7.2
30	1.3	.9	7.1	6.8	8.1	7.2
31	1.2	.7	7.2	6.6	7.9	7.1
32	1.3	.6	7.0	6.8	7.8	7.4
33	1.2	.9	7.2	6.9	7.9	7.5
34	1.3	.8	6.9	7.0	8.2	7.3
35	1.3	.7	7.1	6.5	8.1	7.5
36	1.4	.8	7.2	6.7	8.2	7.2
37	1.5	.9	6.8	6.8	7.8	7.0
38	1.5	.6	6.9	6.9	7.8	7.1
39	1.4	.7	7.2	6.8	8.0	7.3
40	1.4	.9	7.1	6.7	8.1	7.2
TOTALS	54.8	30.5	282.1	270.2	319.8	291.3
AVERAGE	1.37	.7625	7.0525	6.755	7.995	7.2825
ACTUAL VALUE	$\frac{1.37}{250} =$	$\frac{.7625}{250} =$	$\frac{7.0525}{250} =$	$\frac{6.755}{250} =$	$\frac{7.995}{250} =$	$\frac{7.2825}{250} =$
	.00548	.00305	.02821	.02702	.03198	.02913

Sample Calculations

1 (a) Air Space of Wire Mesh by Projection Method

Using data of 60 x 50 – .0070" Mesh

Interstice Length	Interstice Width	Wire Diameter
.0098"	.0124"	.0070"

Area of 1 interstice = $(.0098)(.0124) = .00012152 \text{ in}^2$

No. of interstices = $(60)(50) = 3000$

% air space = $(.00012152)(3000)(100) = \underline{\underline{36.46\%}}$

(b) Using formula method of Phase I

$$\% \text{ air space} = 1 - \left[(60)(.0070) + (50)(.0070) - (60)(50)(.0070)^2\right] = \underline{\underline{37.70\%}}$$

2 (a) Air Space of Fabric by Projection Method

Using data of Fabric #1 – 69 x 78

Interstice Length	Interstice Width	Yarn Diameter
.00962"	.00775"	.0051"

Area of 1 interstice = $(.00962)(.00775) = .000074555 \text{ in}^2$

No. of interstices = $(69)(78) = 5382$

% air space = $(.000074555)(5382)(100) = \underline{\underline{40.13\%}}$

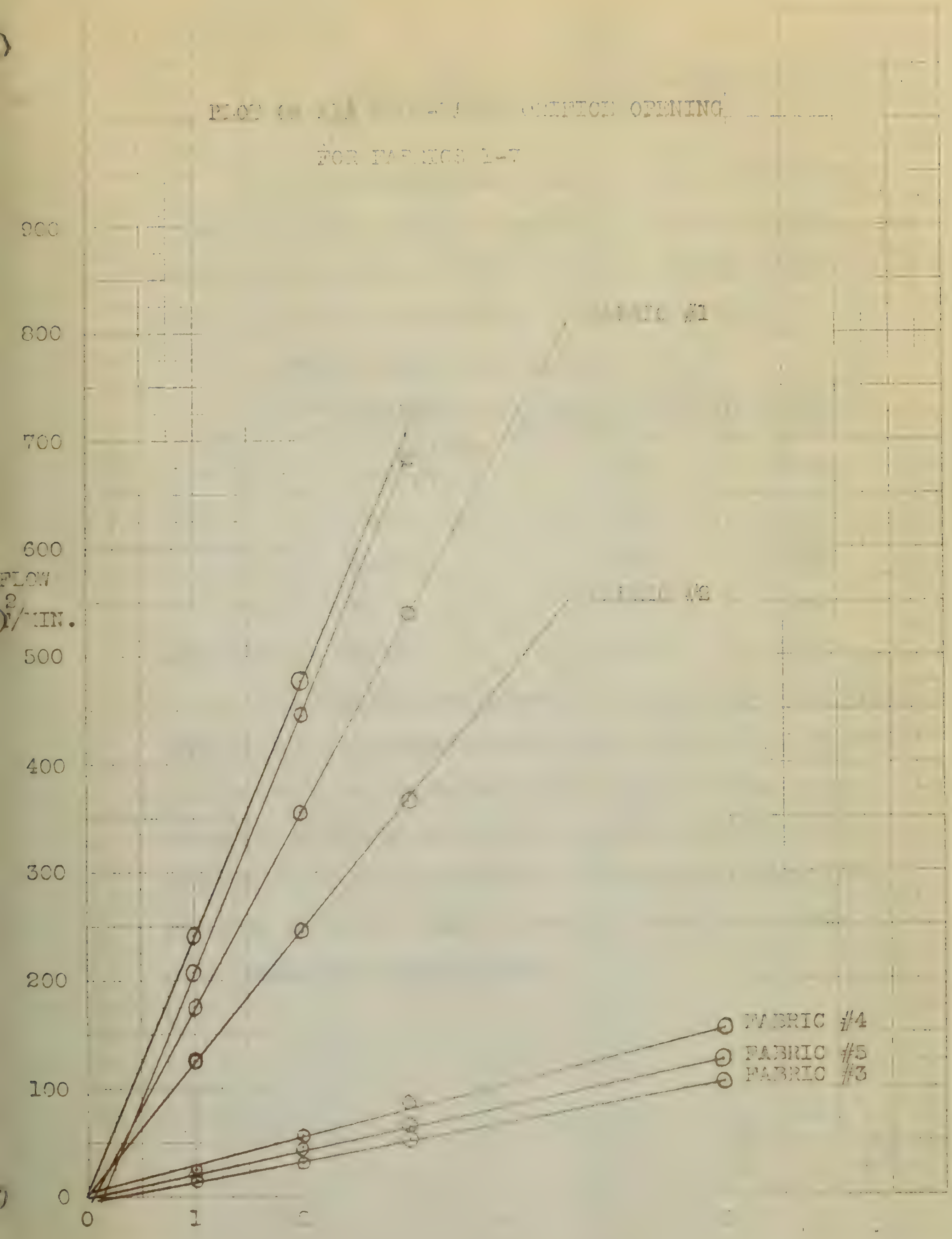
(b) Using formula method of Phase I

$$\% \text{ air space} = 1 - \left\{(69)(.0051) + (78)(.0051) - (69)(78)(.0051)^2\right] = \underline{\underline{39.02\%}}$$

SUMMARY OF DATA - FABRICS

Fabric No. and % Air Space	Air Flow in $ft^3/ft^2/min$. Orifice Area			
	$1 in^2$	$2 in^2$	$3 in^2$	$5.94 in^2$
No. 1 39.58%	174	354	541	720
No. 2 27.99%	123	245	365	720
No. 3 3.24%	17	31	54	108
No. 4 5.62%	26	55	85	154
No. 5 3.84%	21	45	63	124
No. 6 53.51%	242	478	720	-
No. 7 49.19%	207	445	688	720

720 - beyond capacity


PLOT OF AIR [illegible] ORIFICE OPENING

FOR FABRICS 1-7

DISCUSSION AND CONCLUSIONS - PHASE II

The projection method used on the five wire meshes to calculate % air space gave results that were very nearly the same as the results obtained in Phase I of this thesis. Listed below are the comparative values of % air space:

Table of % Air Space Computed by Use of

Wire	Method of Phase I and Formula	Projection Method and Formula	
		Interstice Dimensions	Diameters
60 x 50	37.70	36.46	37.70
30 x 30	51.12	51.84	51.98
18 x 18	41.01	41.99	42.12
24 x 24	39.74	39.99	39.44
120 x 101	37.50	38.17	38.87

The favorable comparison of the use of the two methods (Formula and Projection) was sound basis for proceeding to test the fabrics by the projection method. Listed below are the comparative values of actual flow through the fabrics as taken from Page 55, and the theoretical flow through the fabrics as read from the plot of Page 40 (using the dotted theoretical line between 0 and 30% air space).

Fabric No.	1 in² opening Act.	1 in² opening Theoret.	2 in² opening Act.	2 in² opening Theoret.	3 in² opening Act.	3 in² opening Theoret.	5.94 in² opening Act.	5.94 in² opening Theoret.
1	174	183	354	366	541	549	-	-
2	123	130	245	260	365	390	-	-
3	17	17	31	34	54	51	108	101
4	26	28	55	56	85	84	154	166
5	21	19	45	38	63	57	124	113
6	242	247	478	484	720	741	-	-
7	207	225	445	450	688	675	-	-

Calculating the % error for

Fabric #1 1 in² $\% \text{ Error} = \frac{183 - 174}{183} = 4.9\%$

2 in² $\% \text{ Error} = \frac{366 - 354}{366} = 3.3\%$

3 in² $\% \text{ Error} = \frac{549 - 541}{549} = 1.5\%$

Similar calculations for the other six fabrics were made.

Tabulation appears below:

Fabric No.	% Error 1 in²	% Error 2 in²	% Error 3 in²	% Error 5.94 in²
1	4.9	3.3	1.5	-
2	5.4	5.8	6.4	-
3	0.0	8.8	5.9(-)	6.9(-)
4	7.1	1.8	1.2(-)	7.2
5	10.5(-)	18.4(-)	10.5(-)	9.7(-)
6	2.8	3.2	-	-
7	8.0	1.1	1.9(-)	-

The (-) after the % Error denotes actual flow greater than theoretical flow. Fabric #5 seems to have a consistent error in the minus direction which averages 12.3%. Fabric #5 is a parachute type fabric (see sample on Page 66) and appears to have received very little flattening of yarns as a result of the inter-lacing, consequently seems to be thicker. Perhaps the air space (around the yarns themselves) not lying in the projected theoretical plane is of sufficient magnitude to permit an easier passage of air, a greater quantity of air, through the interstice. If this air space were actually to be considered as a factor in predicting theoretical flow, the % air space would then be higher with a correspondingly higher theoretical air flow through the fabric. This would reduce the % error for Fabric #5, bringing the value closer to 0.

Calculating the average % error for the other six fabrics as a group gives a percentage of 4.4. This is a small per cent error and seems to be low enough to adequately support the basic theory advanced in this thesis for predicting air flow.

The seven fabrics were selected from a group of absolutely unknown structure, yarn count, finish, or type of yarn. As stated before, the only requisite was that the ends and picks appear solid in structure and that some semblance

of regularity and uniformity of interstices be evident when viewing the fabric under 250 magnification. In other words, a fairly evenly constructed fabric was selected. An *accurate* calculation of % air space through the theoretical plane of the fabric can be made under this set of conditions.

CONCLUSIONS - BOTH PHASES

The conclusions of both phases of the thesis are summarized as follows:

Phase I

It is possible to predict within a very slight error the flow of air through wire mesh ranging from 30% to 70% air space by the use of the average equation $y = 15 + 4.3x$ where y = air flow in $ft^3/ft^2/min.$ and x = % air space.

Phase II

With certain restricted conditions imposed on the selection of fabrics, namely, that the ends and picks of the fabric appear solid under 250 magnification and the interstices appear uniform and regular in their size, it is possible to predict the air flow through a fabric by using the plot and average equation referred to above, subject to a small per cent error.

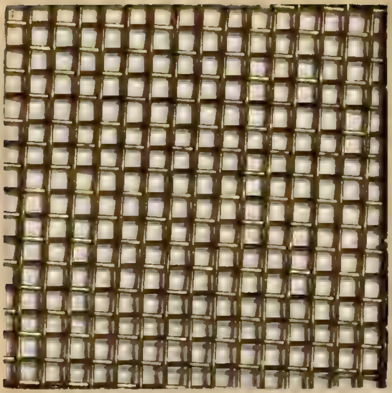
SUGGESTIONS FOR FUTURE WORK

The work done in this thesis has been primarily concerned with uniformly constructed fabrics in the sense that the interstices were all regular and of a rectangular or square shape. The next step would be to investigate more complex fabrics, insuring in each case that an accurate method of calculation of air space in the theoretical plane of the fabric has been used. A further suggestion is to use projection equipment with lower magnification and also project the image of the fabric onto a screen so that several interstices (even for the more open fabrics) can be seen.

It seems desirable to investigate more thoroughly the region between 0% and 30% air space, since most of the ordinary fabrics fall into this category. To aid in this investigation perhaps some finer wire mesh could be used. Another way to approach the problem is to actually construct a fabric uniformly and with a predetermined, pre-calculated air space by using a hand loom. It is conceivable that high twist nylon, perhaps, could easily be used in such a construction to bring about the closest simile to wire mesh. By knowing the count of the nylon being used, and by using the air space formula derived in this thesis, the desired number of ends and picks to give a specific air space could be calculated and then possibly woven on the loom.

ABSTRACT FOR PUBLICATION

This thesis presents a method of predicting air flow through woven fabrics of various materials and of varied constructions. A direct relationship between the air flow and the % air space through the theoretical plane of a fabric has been developed. To accurately calculate % air space, a method of projecting the fabric onto a screen using very high magnification (250) was used. Finally, with the small pressure drop of 0.5 inch of water imposed across the fabric (a factor which denotes streamline, non-turbulent flow), and with the accurate calculation of air space through the theoretical plane of the fabric, air flow can be predicted by using a plot and or an average equation (or formula) derived in this thesis.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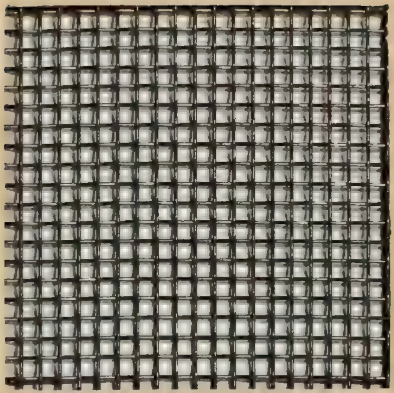
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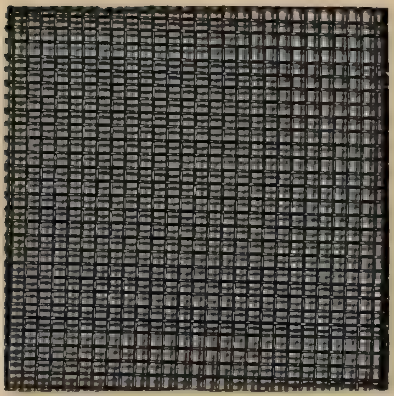
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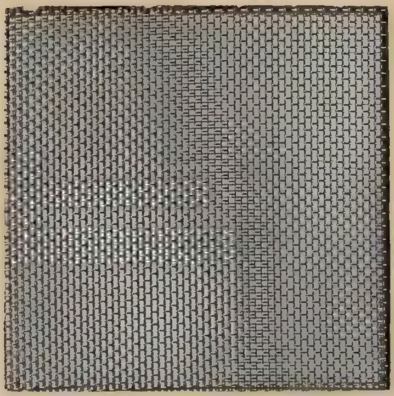
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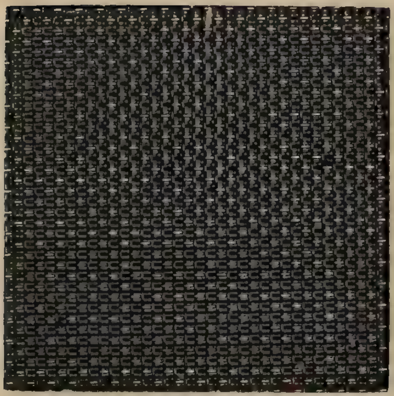
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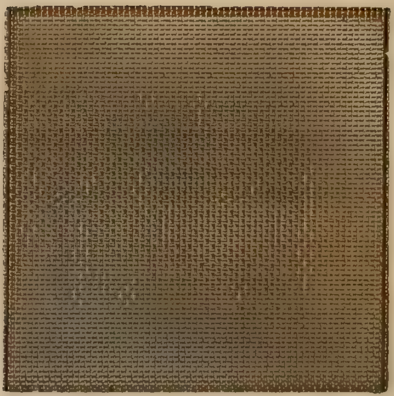
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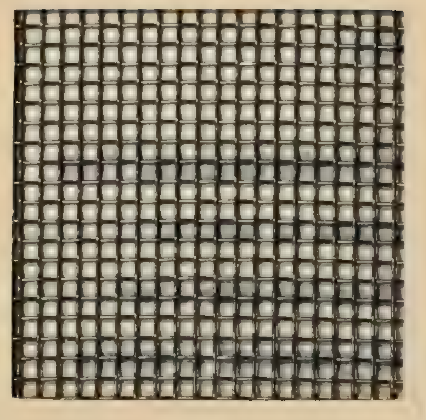

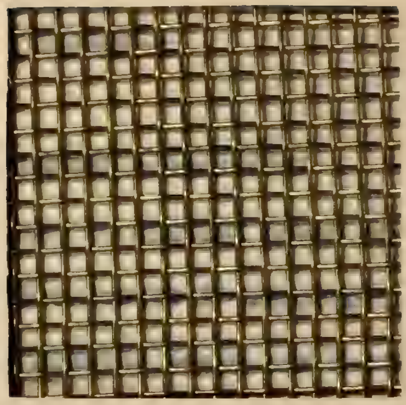

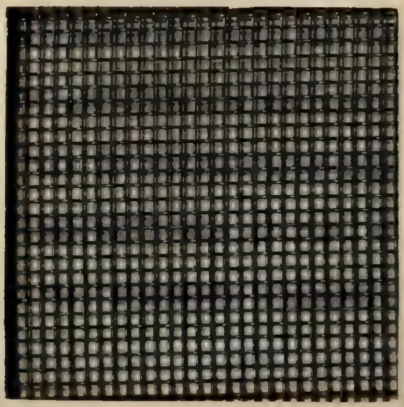

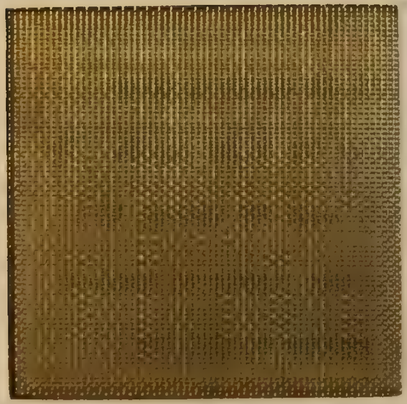

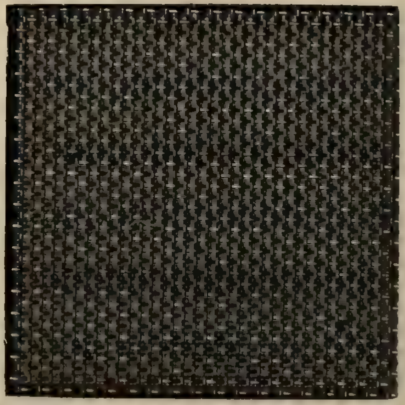

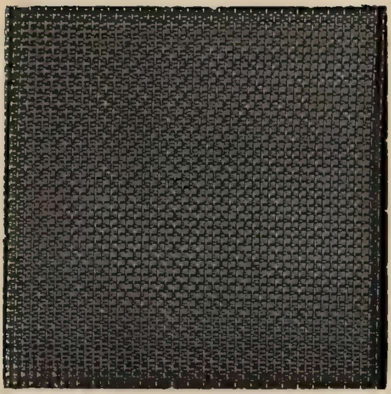

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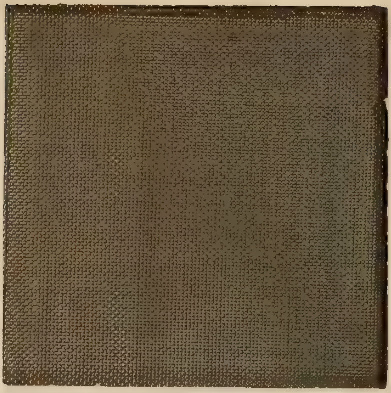

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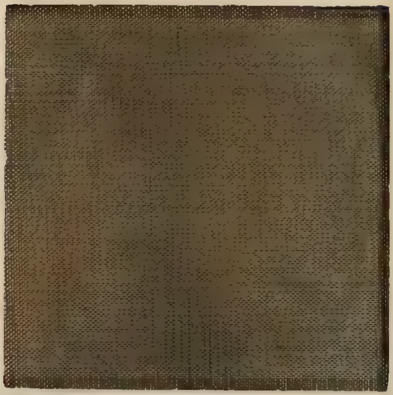

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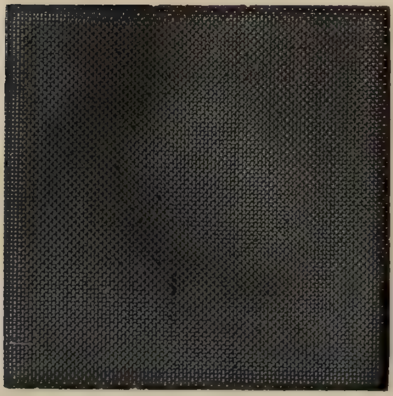

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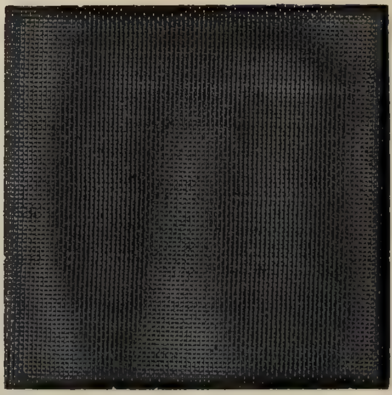

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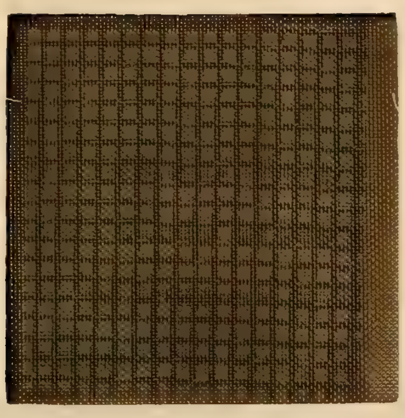
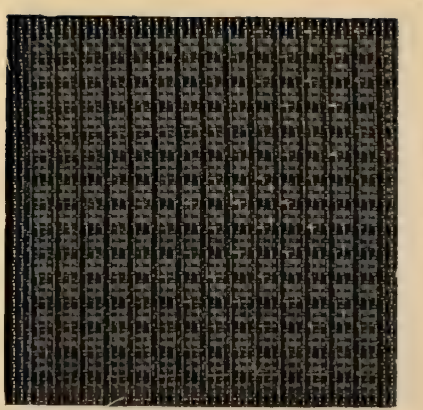
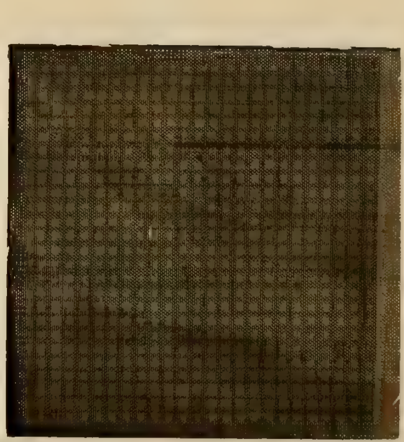
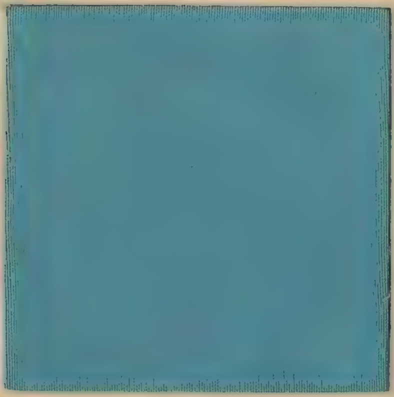






FABRIC #1

FABRIC #2



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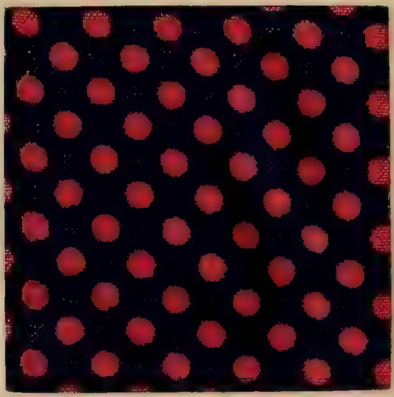

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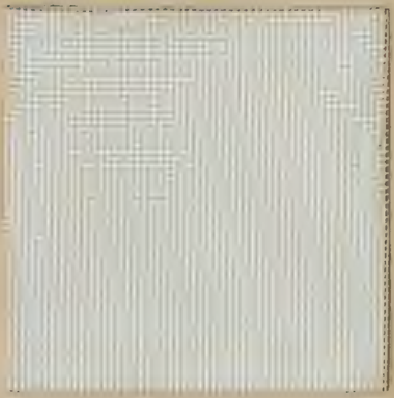
FABRIC #5



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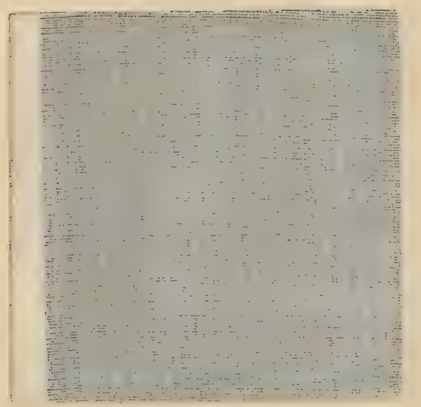

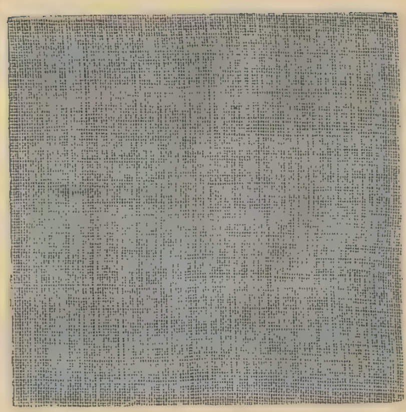

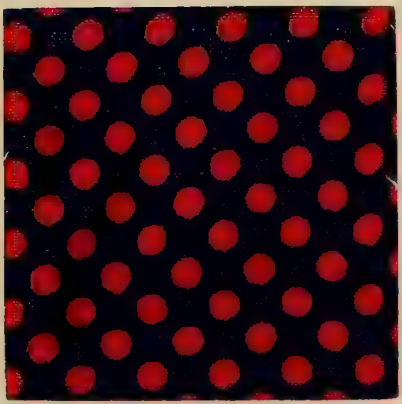

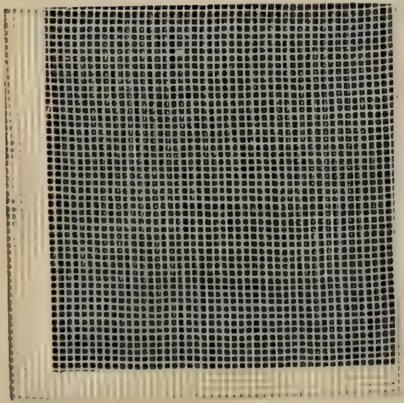

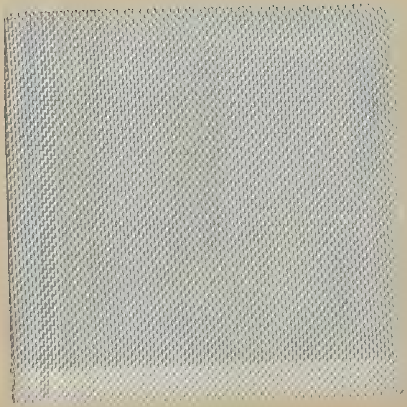

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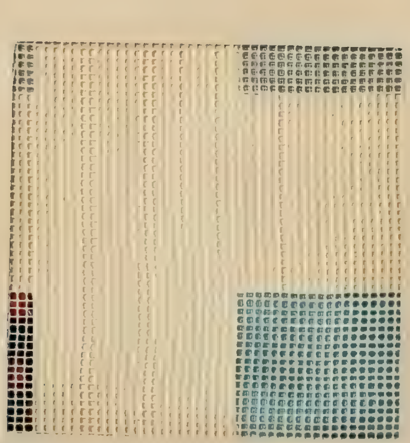

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